

02-29-50  
A

Practitioner's Docket No. ODER-8

PATENT



Preliminary Classification:

Proposed Class:

Subclass:

NOTE: "All applicants are requested to include a preliminary classification on newly filed patent applications. The preliminary classification, preferably class and subclass designations, should be identified in the upper right-hand corner of the letter of transmittal accompanying the application papers, for example 'Proposed Class 2, subclass 129.'" M.P.E.P. § 601, 7th ed.



## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Box Patent Application  
Assistant Commissioner for Patents  
Washington, D.C. 20231

### NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of

Inventor(s): Robin R. Oder, Russell E. Jamison

**WARNING:** 37 C.F.R. § 1.41(a)(1) points out:

"(a) A patent is applied for in the name or names of the actual inventor or inventors.

"(1) The inventorship of a nonprovisional application is that inventorship set forth in the oath or declaration as prescribed by § 1.63, except as provided for in § 1.53(d)(4) and § 1.63(d). If an oath or declaration as prescribed by § 1.63 is not filed during the pendency of a nonprovisional application, the inventorship is that inventorship set forth in the application papers filed pursuant to § 1.53(b), unless a petition under this paragraph accompanied by the fee set forth in § 1.17(i) is filed supplying or changing the name or names of the inventor or inventors."

For (title): METHOD AND APPARATUS FOR SEPARATING MATERIAL

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#### CERTIFICATION UNDER 37 C.F.R. § 1.10\*

(Express Mail label number is **mandatory**.)

(Express Mail certification is **optional**.)

I hereby certify that this New Application Transmittal and the documents referred to as attached therein are being deposited with the United States Postal Service on this date February 25, 2000, in an envelope as "Express Mail Post Office to Addressee," mailing Label Number EL396485567US, addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231.

Tracey L. Milka

(type or print name of person mailing paper)

Signature of person mailing paper

**WARNING:** Certificate of mailing (first class) or facsimile transmission procedures of 37 C.F.R. § 1.8 cannot be used to obtain a date of mailing or transmission for this correspondence.

\***WARNING:** Each paper or fee filed by "Express Mail" **must** have the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 C.F.R. § 1.10(b).

"Since the filing of correspondence under § 1.10 without the Express Mail mailing label thereon is an oversight that can be avoided by the exercise of reasonable care, requests for waiver of this requirement will **not** be granted on petition." Notice of Oct. 24, 1996, 60 Fed. Reg. 56,439, at 56,442.

## 1. Type of Application

This new application is for a(n)

(check one applicable item below)

- Original (nonprovisional)
- Design
- Plant

**WARNING:** *Do not use this transmittal for a completion in the U.S. of an International Application under 35 U.S.C. § 371(c)(4), unless the International Application is being filed as a divisional, continuation or continuation-in-part application.*

**WARNING:** *Do not use this transmittal for the filing of a provisional application.*

**NOTE:** *If one of the following 3 items apply, then complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF A PRIOR U.S. APPLICATION CLAIMED and a NOTIFICATION IN PARENT APPLICATION OF THE FILING OF THIS CONTINUATION APPLICATION.*

- Divisional.
- Continuation.
- Continuation-in-part (C-I-P).

## 2. Benefit of Prior U.S. Application(s) (35 U.S.C. §§ 119(e), 120, or 121)

**NOTE:** *A nonprovisional application may claim an invention disclosed in one or more prior filed copending nonprovisional applications or copending international applications designating the United States of America. In order for a nonprovisional application to claim the benefit of a prior filed copending nonprovisional application or copending international application designating the United States of America, each prior application must name as an inventor at least one inventor named in the later filed nonprovisional application and disclose the named inventor's invention claimed in at least one claim of the later filed nonprovisional application in the manner provided by the first paragraph of 35 U.S.C. § 112. Each prior application must also be:*

- (i) An international application entitled to a filing date in accordance with PCT Article 11 and designating the United States of America; or*
- (ii) Complete as set forth in § 1.51(b); or*
- (iii) Entitled to a filing date as set forth in § 1.53(b) or § 1.53(d) and include the basic filing fee set forth in § 1.16; or*
- (iv) Entitled to a filing date as set forth in § 1.53(b) and have paid therein the processing and retention fee set forth in § 1.21(l) within the time period set forth in § 1.53(f).*

*37 C.F.R. § 1.78(a)(1).*

**NOTE:** *If the new application being transmitted is a divisional, continuation or a continuation-in-part of a parent case, or where the parent case is an International Application which designated the U.S., or benefit of a prior provisional application is claimed, then check the following item and complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.*

**WARNING:** *If an application claims the benefit of the filing date of an earlier filed application under 35 U.S.C. §§ 120, 121 or 365(c), the 20-year term of that application will be based upon the filing date of the earliest U.S. application that the application makes reference to under 35 U.S.C. §§ 120, 121 or 365(c). (35 U.S.C. § 154(a)(2) does not take into account, for the determination of the patent term, any application on which priority is claimed under 35 U.S.C. §§ 119, 365(a) or 365(b).) For a c-i-p application, applicant should review whether any claim in the patent that will issue is supported by an earlier application and, if not, the applicant should consider canceling the reference to the earlier filed application. The term of a patent is not based on a claim-by-claim approach. See Notice of April 14, 1995, 60 Fed. Reg. 20,195, at 20,205.*

**WARNING:** When the last day of pendency of a provisional application falls on a Saturday, Sunday, or Federal holiday within the District of Columbia, any nonprovisional application claiming benefit of the provisional application **must** be filed prior to the Saturday, Sunday, or Federal holiday within the District of Columbia. See 37 C.F.R. § 1.78(a)(3).

- The new application being transmitted claims the benefit of prior U.S. application(s). Enclosed are ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

### 3. Papers Enclosed

- A. Required for filing date under 37 C.F.R. § 1.53(b) (Regular) or 37 C.F.R. § 1.153 (Design) Application

53 Pages of specification

8 Pages of claims

19 Sheets of drawing

**WARNING:** DO NOT submit original drawings. A high quality copy of the drawings should be supplied when filing a patent application. The drawings that are submitted to the Office must be on strong, white, smooth, and non-shiny paper and meet the standards according to § 1.84. If corrections to the drawings are necessary, they should be made to the original drawing and a high-quality copy of the corrected original drawing then submitted to the Office. Only one copy is required or desired. For comments on proposed then-new 37 C.F.R. § 1.84, see Notice of March 9, 1988 (1990 O.G. 57-62).

**NOTE:** "Identifying indicia, if provided, should include the application number or the title of the invention, inventor's name, docket number (if any), and the name and telephone number of a person to call if the Office is unable to match the drawings to the proper application. This information should be placed on the back of each sheet of drawing a minimum distance of 1.5 cm. (5/8 inch) down from the top of the page . . ." 37 C.F.R. § 1.84(c)).

(complete the following, if applicable)

- The enclosed drawing(s) are photograph(s), and there is also attached a "PETITION TO ACCEPT PHOTOGRAPH(S) AS DRAWING(S)." 37 C.F.R. § 1.84(b).
- formal
- informal

### B. Other Papers Enclosed

2 Pages of declaration and power of attorney

2 Pages of abstract

0 Other

### 4. Additional papers enclosed

- Amendment to claims
- Cancel in this applications claims \_\_\_\_\_ before calculating the filing fee. (At least one original independent claim must be retained for filing purposes.)
- Add the claims shown on the attached amendment. (Claims added have been numbered consecutively following the highest numbered original claims.)
- Preliminary Amendment
- Information Disclosure Statement (37 C.F.R. § 1.98)
- Form PTO-1449 (PTO/SB/08A and 08B)
- Citations

- Declaration of Biological Deposit
- Submission of "Sequence Listing," computer readable copy and/or amendment pertaining thereto for biotechnology invention containing nucleotide and/or amino acid sequence.
- Authorization of Attorney(s) to Accept and Follow Instructions from Representative
- Special Comments
- Other

##### **5. Declaration or oath (including power of attorney)**

*NOTE: A newly executed declaration is not required in a continuation or divisional application provided that the prior nonprovisional application contained a declaration as required, the application being filed is by all or fewer than all the inventors named in the prior application, there is no new matter in the application being filed, and a copy of the executed declaration filed in the prior application (showing the signature or an indication thereon that it was signed) is submitted. The copy must be accompanied by a statement requesting deletion of the names of person(s) who are not inventors of the application being filed. If the declaration in the prior application was filed under § 1.47, then a copy of that declaration must be filed accompanied by a copy of the decision granting § 1.47 status or, if a nonsigning person under § 1.47 has subsequently joined in a prior application, then a copy of the subsequently executed declaration must be filed. See 37 C.F.R. §§ 1.63(d)(1)-(3).*

*NOTE: A declaration filed to complete an application must be executed, identify the specification to which it is directed, identify each inventor by full name including family name and at least one given name, without abbreviation together with any other given name or initial, and the residence, post office address and country or citizenship of each inventor, and state whether the inventor is a sole or joint inventor. 37 C.F.R. § 1.63(a)(1)-(4).*

*NOTE: "The inventorship of a nonprovisional application is that inventorship set forth in the oath or declaration as prescribed by § 1.62, except as provided for in § 1.53(d)(4) and § 1.63(d). If an oath or declaration as prescribed by § 1.63 is not filed during the pendency of a nonprovisional application, the inventorship is that inventorship set forth in the application papers filed pursuant to § 1.53(b), unless a petition under this paragraph accompanied by the fee set forth in § 1.17(i) is filed supplying or changing the name or names of the inventor or inventors." 37 C.F.R. § 1.41(a)(1).*

Enclosed

Executed by

(check all applicable boxes)

- inventor(s).
- legal representative of inventor(s).  
37 C.F.R. §§ 1.42 or 1.43.
- joint inventor or person showing a proprietary interest on behalf of inventor who refused to sign or cannot be reached.
  - This is the petition required by 37 C.F.R. § 1.47 and the statement required by 37 C.F.R. § 1.47 is also attached. See item 13 below for fee.
- Not Enclosed.

*NOTE: Where the filing is a completion in the U.S. of an International Application or where the completion of the U.S. application contains subject matter in addition to the International Application, the application may be treated as a continuation or continuation-in-part, as the case may be, utilizing ADDED PAGE FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION CLAIMED.*

- Application is made by a person authorized under 37 C.F.R. § 1.41(c) on behalf of all the above named inventor(s).

*(The declaration or oath, along with the surcharge required by 37 C.F.R. § 1.16(e) can be filed subsequently).*

- Showing that the filing is authorized.  
*(not required unless called into question. 37 C.F.R. § 1.41(d))*

## 6. Inventorship Statement

**WARNING:** *If the named inventors are each not the inventors of all the claims an explanation, including the ownership of the various claims at the time the last claimed invention was made, should be submitted.*

The inventorship for all the claims in this application are:

- The same.

**or**

- Not the same. An explanation, including the ownership of the various claims at the time the last claimed invention was made,  
 is submitted.  
 will be submitted.

## 7. Language

**NOTE:** *An application including a signed oath or declaration may be filed in a language other than English. An English translation of the non-English language application and the processing fee of \$130.00 required by 37 C.F.R. § 1.17(k) is required to be filed with the application, or within such time as may be set by the Office. 37 C.F.R. § 1.52(d).*

- English  
 Non-English  
 The attached translation includes a statement that the translation is accurate. 37 C.F.R. § 1.52(d).

## 8. Assignment

- An assignment of the invention to EXPORTech Company, Inc.

- 
- is attached. A separate  "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or  FORM PTO 1595 is also attached.  
 will follow.

**NOTE:** *"If an assignment is submitted with a new application, send two separate letters-one for the application and one for the assignment." Notice of May 4, 1990 (1114 O.G. 77-78).*

**WARNING:** *A newly executed "CERTIFICATE UNDER 37 C.F.R. § 3.73(b)" must be filed when a continuation-in-part application is filed by an assignee. Notice of April 30, 1993, 1150 O.G. 62-64.*

(New Application Transmittal [4-1]—page 5 of 11)

**9. Certified Copy**

Certified copy(ies) of application(s)

Country	Appn. No.	Filed
Country	Appn. No.	Filed
Country	Appn. No.	Filed

from which priority is claimed

- is (are) attached.
  - will follow.

**NOTE:** The foreign application forming the basis for the claim for priority must be referred to in the oath or declaration. 37 C.F.R. § 1.55(a) and 1.63.

**NOTE:** This item is for any foreign priority for which the application being filed directly relates. If any parent U.S. application or International Application from which this application claims benefit under 35 U.S.C. § 120 is itself entitled to priority from a prior foreign application, then complete item 18 on the ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

**10. Fee Calculation (37 C.F.R. § 1.16)**

**A.  Regular application**

CLAIMS AS FILED				
Number filed	Number Extra	Rate	Basic Fee	
			37 C.F.R. § 1.16(a)	
			\$690.00	
<b>Total</b>				
Claims (37 C.F.R. § 1.16(c))	47 - 20 = 27	×	\$ 18.00	486.00
<b>Independent</b>				
Claims (37 C.F.R. § 1.16(b))	5 - 3 = 2	×	\$ 78.00	156.00
Multiple dependent claim(s), if any (37 C.F.R. § 1.16(d))		+	\$260.00	

- Amendment cancelling extra claims is enclosed.
  - Amendment deleting multiple-dependencies is enclosed.
  - Fee for extra claims is not being paid at this time.

**NOTE:** If the fees for extra claims are not paid on filing they must be paid or the claims cancelled by amendment, prior to the expiration of the time period set for response by the Patent and Trademark Office in any notice of fee deficiency. 37 C.F.R. § 1.16(d).

**Filing Fee Calculation** \$ 1,332.00

**B.**  Design application

(\$310.00—37 C.F.R. § 1.16(f))

## Filing Fee Calculation

- C.  Plant application  
(\$480.00—37 C.F.R. § 1.16(g))

Filing fee calculation \$ \_\_\_\_\_

**11. Small Entity Statement(s)**

- Statement(s) that this is a filing by a small entity under 37 C.F.R. § 1.9 and 1.27 is (are) attached.

**WARNING:** "Status as a small entity must be specifically established in each application or patent in which the status is available and desired. Status as a small entity in one application or patent does not affect any other application or patent, including applications or patents which are directly or indirectly dependent upon the application or patent in which the status has been established. The refiling of an application under § 1.53 as a continuation, division, or continuation-in-part (including a continued prosecution application under § 1.53(d)), or the filing of a reissue application requires a new determination as to continued entitlement to small entity status for the continuing or reissue application. A nonprovisional application claiming benefit under 35 U.S.C. § 119(e), 120, 121, or 365(c) of a prior application, or a reissue application may rely on a statement filed in the prior application or in the patent if the nonprovisional application or the reissue application includes a reference to the statement in the prior application or in the patent or includes a copy of the statement in the prior application or in the patent and status as a small entity is still proper and desired. The payment of the small entity basic statutory filing fee will be treated as such a reference for purposes of this section." 37 C.F.R. § 1.28(a)(2).

**WARNING:** "Small entity status must not be established when the person or persons signing the . . . statement can unequivocally make the required self-certification." M.P.E.P., § 509.03, 6th ed., rev. 2, July 1996 (emphasis added).

(complete the following, if applicable)

- Status as a small entity was claimed in prior application

\_\_\_\_\_ / \_\_\_\_\_, filed on \_\_\_\_\_, from which benefit is being claimed for this application under:

- 35 U.S.C. §  119(e),  
 120,  
 121,  
 365(c),

and which status as a small entity is still proper and desired.

- A copy of the statement in the prior application is included.

Filing Fee Calculation (50% of A, B or C above)

\$ 666.00

**NOTE:** Any excess of the full fee paid will be refunded if small entity status is established and a refund request are filed within 2 months of the date of timely payment of a full fee. The two-month period is not extendable under § 1.136. 37 C.F.R. § 1.28(a).

**12. Request for International-Type Search (37 C.F.R. § 1.104(d))**

(complete, if applicable)

- Please prepare an international-type search report for this application at the time when national examination on the merits takes place.

**13. Fee Payment Being Made at This Time**

- Not Enclosed
- No filing fee is to be paid at this time.  
*(This and the surcharge required by 37 C.F.R. § 1.16(e) can be paid subsequently.)*
- Enclosed
- Filing fee \$ 666.00
- Recording assignment  
(\$40.00; 37 C.F.R. § 1.21(h))  
(See attached "COVER SHEET FOR  
ASSIGNMENT ACCOMPANYING NEW  
APPLICATION".) \$ 40.00
- Petition fee for filing by other than all the inventors or person on behalf of the inventor where inventor refused to sign or cannot be reached  
(\$130.00; 37 C.F.R. §§ 1.47 and 1.17(i)) \$ \_\_\_\_\_
- For processing an application with a specification in a non-English language  
(\$130.00; 37 C.F.R. §§ 1.52(d) and 1.17(k)) \$ \_\_\_\_\_
- Processing and retention fee  
(\$130.00; 37 C.F.R. §§ 1.53(d) and 1.21(l)) \$ \_\_\_\_\_
- Fee for international-type search report  
(\$40.00; 37 C.F.R. § 1.21(e)) \$ \_\_\_\_\_

**NOTE:** 37 C.F.R. § 1.21(l) establishes a fee for processing and retaining any application that is abandoned for failing to complete the application pursuant to 37 C.F.R. § 1.53(f) and this, as well as the changes to 37 C.F.R. §§ 1.53 and 1.78(a)(1), indicate that in order to obtain the benefit of a prior U.S. application, either the basic filing fee must be paid, or the processing and retention fee of § 1.21(l) must be paid, within 1 year from notification under § 53(f).

Total fees enclosed \$ 706.00

**14. Method of Payment of Fees**

- Check in the amount of \$ 666.00 & 40.00
- Charge Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_

A duplicate of this transmittal is attached.

**NOTE:** Fees should be itemized in such a manner that it is clear for which purpose the fees are paid. 37 C.F.R. § 1.22(b).

## **15. Authorization to Charge Additional Fees**

**WARNING:** If no fees are to be paid on filing, the following items should not be completed.

**WARNING:** Accurately count claims, especially multiple dependent claims, to avoid unexpected high charges, if extra claim charges are authorized.

- The Commissioner is hereby authorized to charge the following additional fees by this paper and during the entire pendency of this application to Account No. 19-0737:

- 37 C.F.R. § 1.16(a), (f) or (g) (filing fees)  
 37 C.F.R. § 1.16(b), (c) and (d) (presentation of extra claims)

**NOTE:** Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid on these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.16(d)), it might be best not to authorize the PTO to charge additional claim fees, except possibly when dealing with amendments after final action.

- 37 C.F.R. § 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)  
 37 C.F.R. § 1.17(a)(1)–(5) (extension fees pursuant to § 1.136(a)).  
 37 C.F.R. § 1.17 (application processing fees)

**NOTE:** ". . . A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).

- 37 C.F.R. § 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. § 1.311(b))

**NOTE:** Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 C.F.R. § 1.311(b).

**NOTE:** 37 C.F.R. § 1.28(b) requires "Notification of any change in status resulting in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying, . . . the issue fee. . ." From the wording of 37 C.F.R. § 1.28(b), (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

## 16. Instructions as to Overpayment

NOTE: ". . . Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).

- Credit Account No. 19-0737
- Refund



SIGNATURE OF PRACTITIONER

Reg. No. 30,587

Ansel M. Schwartz

(type or print name of attorney)

One Sterling Plaza

201 N. Craig Street, Suite 304

P.O. Address

Pittsburgh, PA 15213

**Incorporation by reference of added pages**

*(check the following item if the application in this transmittal claims the benefit of prior U.S. application(s) (including an international application entering the U.S. stage as a continuation, divisional or C-I-P application) and complete and attach the ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED)*

- Plus Added Pages for New Application Transmittal Where Benefit of Prior U.S. Application(s) Claimed

Number of pages added \_\_\_\_\_

- Plus Added Pages for Papers Referred to in Item 4 Above

Number of pages added \_\_\_\_\_

- Plus added pages deleting names of inventor(s) named in prior application(s) who is/are no longer inventor(s) of the subject matter claimed in this application.

Number of pages added \_\_\_\_\_

- Plus "Assignment Cover Letter Accompanying New Application"

Number of pages added \_\_\_\_\_ 4

- Statement Where No Further Pages Added**

*(if no further pages form a part of this Transmittal, then end this Transmittal with this page and check the following item)*

- This transmittal ends with this page.

Practitioner's Docket No. ODER-8**PATENT**

Applicant Robin R. Oder       Patentee \_\_\_\_\_  
 Application No. \_\_\_\_\_       Patent No. \_\_\_\_\_  
 Filed on \_\_\_\_\_       Issued on \_\_\_\_\_  
Title: METHOD AND APPARATUS FOR SEPARATING MATERIAL

**STATEMENT CLAIMING SMALL ENTITY STATUS  
(37 CFR 1.9(f) and 1.27(c))—SMALL BUSINESS CONCERN**

I hereby state that I am

- the owner of the small business concern identified below;  
 an official of the small business concern empowered to act on behalf of the concern identified below;

Name of Small Business Concern EXPORTech Company, Inc.

Address of Small Business Concern Building 242, Schreiber Industrial District, 12th Street, P.O. Box 588, New Kensington, PA 15068-0588

I hereby state that the above identified small business concern qualifies as a small business concern, as defined in 13 CFR 121.12, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office under Sections 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third-party or parties controls or has the power to control both.

I hereby state that rights under contract or law have been conveyed to, and remain with, the small business concern identified above, with regard to the invention described in

- the specification filed herewith, with title as listed above.  
 the application identified above.  
 the patent identified above.

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights in the invention is listed below\* and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(e), if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

\*NOTE: Separate statements are required from each named person, concern or organization having rights to the invention as to their status as small entities. (37 CFR 1.27)

Each such person, concern or organization having any rights in the invention is listed below:

- No such person, concern, or organization exists.  
 Each such person, concern or organization is listed below.

Name \_\_\_\_\_  
Address \_\_\_\_\_

INDIVIDUAL       SMALL BUSINESS CONCERN       NONPROFIT ORGANIZATION

Name \_\_\_\_\_  
Address \_\_\_\_\_

INDIVIDUAL       SMALL BUSINESS CONCERN       NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small business entity is no longer appropriate. (37 CFR 1.28(b))

(check the following item, if desired)

NOTE: The following verification statement need not be made in accordance with the rules published on Oct. 10, 1997, 52 Fed. Reg. 52,131, effective Dec. 1, 1997.

NOTE: "The presentation to the Office (whether by signing, filing, submitting, or later advocating) of any paper by a party, whether a practitioner or non-practitioner, constitutes a certification under § 10.18(b) of this chapter. Violations of § 10.18(b)(2) of this chapter by a party, whether a practitioner or non-practitioner, may result in the imposition of sanctions under § 10.18(c) of this chapter. Any practitioner violating § 10.18(b) may also be subject to disciplinary action. See §§ 10.18(d) and 10.29(c)(15)." 37 C.F.R. § 1.4(e)(2).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Person Signing Robin R. Oder  
Title of Person if Other Than Owner President  
Address of Person Signing EXPORTech Company, Inc., Building 242,  
Schreiber Industrial District, 12th Street, P.O. Box 588,  
New Kensington, PA 15068-0588

SIGNATURE

Robin R. Oder

Date February 24, 2000

(Small Entity—Small Business [7-4]—page 2 of 2)

METHOD AND APPARATUS FOR SEPARATING MATERIAL

This invention was made with Government support under Grant DE-FG05-94ER81764 awarded by the Department of Energy. The Government has certain rights in this invention.

5

FIELD OF THE INVENTION

The invention is in the field of physical separation of particulate matter. Specifically, the invention relates to the operation of a comminution device as a size reducing device, as concentrator, and as a separator of less friable particles liberated from the feed matrix in the grinding operation. More specifically, the invention is in the field of physical separation of particles removed from the comminution device to recover desirable particles from return to the comminution device.

BACKGROUND OF THE INVENTION

15           Comminutors are employed to reduce the size of particles to a range which is desirable and to liberate impurities so that they can be removed downstream of comminution. The feed particles may range in size up to several inches while the product particles may range from inches down to microns in size. More comminution  
20 energy is required to bring a mixture of particles of widely ranging friabilities to the desired size than when the friable components alone are present. The invention relates to reducing comminution energy consumption and increasing the throughput of comminutors while improving the quality of the  
25 product of comminution by separating the friable and less friable components as they are liberated from the feed matrix within the grinding operation and before the hard component is overground. Specifically, the invention relates to modification and operation of comminuting devices and their classifiers, if they are used, so

as to separate two streams from the comminution device. One is concentrated in the hard and less friable components liberated from the feed in the grinding operation. This may be either an impurity or a valuable component of the feed. The other is concentrated in  
5 the friable component of the feed. More specifically, the invention relates to combining the operation of a comminution device and a separation device so as to separate the hard components of the feed as they are liberated inside the comminutor but before they are overground. Separation methods based on  
10 gravity, size classification, dry magnetic separation, and triboelectric means are used to separate hard material form friable material found in a mill concentrated steam taken from the comminution device. Particulate matter of differing chemical and physical makeup can have different magnetic properties and may be  
15 electrically charged by contact and friction, tribocharging. By including triboelectric separation means, modified dry magnetic separators can be effective in recovering friable material of a great range of types from the mill concentrated fraction taken from the mill. By this combined pulverizer-separator operation, the  
20 MagMill™ can produce high quality comminution products without significant loss of the desired component. The friable material so separated is returned to the grinding zone for grinding to product fineness while the hard component is collected separately and not returned to the mill. By this means, both the quality and  
25 the recovery of the separated components are improved when compared to that of the state-of-the-art technology in which everything is reduced to the same size consist and then separated downstream of the comminution device.

The invention is distinguished from the state-of-the-art by  
30 processing a significant amount of the particles circulating inside the comminution device. In current technology, tramp iron exits are employed to separate very small amounts of hard and abrasive

material before it destroys the inside of the grinding device. The rate of withdrawal of this undesirable material is typically less than 1/10% of the rate of feed to the comminutor. The desired goal is protection of the grinding device, not improvement of the quality of the product or increasing throughput and decreasing power draw. By contrast, the present invention preferentially extracts material from the inside of the comminutor which is concentrated in hard components of the feed. Indeed, if it is desired to improve the quality of the product, then the amount of material to be separated from the inside of the comminutor must be sufficient to have an effect. One tenth of one percent, generally, is not enough. The required amount is dependent upon the concentration of hard components in the withdrawn material and the recovery of more friable material from this stream which is subsequently returned to the comminutor for grinding to size specification. The present invention is unique in showing how and where to withdraw this material from the comminutor and in employing unique and powerful methods for recovery of the friable component inadvertently withdrawn from the internally circulating stream inside the comminutor.

Indeed, it has been discovered that particles of quality the same as or worse than that withdrawn from the tramp metal chutes can be withdrawn from the inside of a coal pulverizer at locations several feet above the throat area where air enters and tramp metal exits. This has been observed in grinding a blend of raw coals from North Central Pennsylvania in an ABB C.E. Raymond 633 bowl mill. For this mill, coal was withdrawn from the pyrite trap at the rate of 67 pounds per hour. This is small compared to the nominal 12-15 TPH fed to the pulverizer. The coal withdrawn from the pyrite traps had an ash level of 69.1 Wt.% and a sulfur level of 23.4 Wt.%. In the experimental tests, coal was withdrawn at the rate of 8.2 Lb/Hr from a sampling port located several feet

above the top of the grinding bowl in the region which is open for air flow upward. While the particle size was smaller than that withdrawn from the pyrite traps, it had an ash level of 58.1 Wt.% and a sulfur level 33.6 Wt.%. This illustrates the potential for 5 separation of refuse quality material from the flow of particles inside the pulverizer.

By way of example, coal is dry-milled to 200 mesh (74 micron) topsize at pulverized-coal fired power plants to promote good combustion characteristics. [See, for example, Steam, Its 10 Generation and Use, Chapter 9, "Preparation and Utilization of Pulverized Coal," Babcock & Wilcox, New York, NY, 1978, and Combustion Fossil Power Systems, A Reference Book on Fuel Burning and Steam Generation, Ed., Joseph G. Singer, Chapter 12, "Pulverizers and Pulverized-Coal Systems," Combustion Engineering, Inc., Windsor, CT 1981, incorporated by reference herein]. The fine 15 coal generated in the pulverizer is air-conveyed out of the mill directly to the burner. Coincidentally, grinding to 200 mesh is also effective in liberating fine minerals encased in the feed-coal particles even after the coal has been cleaned using conventional wet processing technology. However, other than tramp iron chutes 20 called pyrite traps for removing small amounts of pyrites and other coarse debris, no means are employed in the coal pulverizers now used to separate minerals which are liberated there. Separation of hard minerals at the pulverizer would improve operation of the 25 power plant by increasing the pulverizer throughput and reducing the power draw, by reducing abrasive wear, by reducing slagging, fouling, and water wall wastage in the furnace, by reducing emissions of sulfur and other hazardous air pollutants such as trace metals associated with minerals in the coal, including 30 mercury, and arsenic which is deleterious to the operation of catalytic scrubbers used in post combustion separation of sulfur and nitrogen oxides.

The bulk of the hydrocarbon structure of bituminous coals is much softer than the minerals commonly found in coal. Consequently, hard minerals require more passes through the mill's grinding zone to reach product size specification (70% to 80% finer 5 than 74 microns particle diameter) than does the soft coal. Because of this, the concentration of hard minerals is greater in the stream of oversize particles circulating inside the pulverizer (internal circulation) than it is in the feed coal. Iron pyrite, one of these minerals, is one of the hardest and most abrasive 10 minerals commonly found in coal. Trace metals such as mercury, arsenic, and selenium are known to preferentially associate with iron sulfide minerals such as pyrites. Consequently, removal of refuse concentrated in the mill circulation can significantly lower the ash, sulfur, and trace metal levels in the mill product.

15           The logical place for fine coal cleaning is in the pulverizers, which are already used by the power plant. Indeed, EXPORTech Company, Inc. (Y. Feng, R.R. Oder, R.W. DeSollar, E.A Stephens, Jr., G.F. Teacher and T.L. Banfield, "Dry Coal Cleaning in a MagMill, appearing in the Proceedings of the 22<sup>nd</sup> International  
20 Technical Conference on Coal Utilization and Fuel Systems," Clearwater, FL, March 16-19, 1997; See also R.R. Oder, R.E. Jamison, and E.D. Brandner, "Preliminary Results of Pre-Combustion Removal of Mercury, Arsenic, and Selenium from Coal by Dry Magnetic Separation," appearing in the Proceedings of the 24<sup>th</sup> International  
25 Technical Conference on Coal Utilization & Fuel Systems, Clearwater, FL, March 8-11, 1999, pp. 151-158, incorporated by reference herein) has shown that refuse with high levels of ash and sulfur can be separated from the internal circulation of almost all commercial pulverizers used at power plants and that removal of  
30 this refuse from the mill can lower the ash and sulfur levels and reduce the levels of toxic trace elements in the pulverized product. ETCi has further demonstrated that dry magnetic

separation can be used to recover clean coal from the refuse (R.R. Oder, R.E. Jamison, and J.R. Davis, "Coal Cleaning at Pulverized-Coal Fired Power Plants," Proc. 11<sup>th</sup> Annual Pittsburgh Coal Conference - Coal: Energy and the Environment, Sept. 12-16, 1994,  
5 Pittsburgh, PA, Ed., S-H Chiang, pp. 640-645 (1994), incorporated by reference herein). Additionally, ETCi has suggested that the combined process of pulverization, size and density classification in the mill, dry magnetic separation for recovery of clean coal from the mill refuse, plus return of the clean coal to the  
10 pulverizer for grinding to product fineness, is a novel method for efficient separation of ash forming minerals, sulfur, and hazardous pollutants from the coal fed to a pulverized-coal fired power plant. This novel method is not practiced in the electric power industry because of the significant engineering challenge  
15 associated with removal of a concentrated stream of refuse from the pulverizers. This obstacle has now been overcome and is the basis for the invention disclosed here.

It is important to note that others have used magnetic separation to separate hard gangue material from the feed to  
20 pulverizers, which is standard practice in the industry, and some also to recover the value component from the underflow in the pyrite traps or tramp metal chutes employed in most grinding mills. While this material may be blended with the product or returned to the mill for further grinding, these efforts have treated only a  
25 small amount of the material fed to the mill. The current invention is greatly different from these past efforts in two major ways. First, large amounts of material are extracted from the internal circulation of the mill from locations other than the tramp iron chutes. Secondly, powerful magnetic separation  
30 techniques are employed which have the capability for separation of materials ranging from strongly magnetic to diamagnetic. Indeed, with the addition of triboelectric phenomena (ElectriMag™ Separator

co-pending application having Serial Number 09/289,929 filed on April 14, 1999, incorporated by reference herein), the method is now capable of separating particles based on both magnetic and surface charging characteristics. The present invention goes far 5 beyond the present state-of-the-art. For this reason, the technology is not restricted to conventional applications to separation of strongly magnetic particles from inert materials. With the combined action of the pulverizer to liberate on the basis 10 of differences in friability and the electric/magnetic separation mechanism employed, the technology can be applied to a wide range of important new applications.

Friability generally has to do with the ease with which small particles can be made in a comminutor. More friable particles produce a greater amount of finer particles than do less friable particles. Generally speaking, friability is related to the hardness of the material and to its ability to fracture which is related in a complex way to fundamental physical characteristics such as crack propagation in the solid. (Klaus Schonert, "Aspects of Very Fine Grinding," Chapter 9 in Challenges in Mineral 15 Processing, Proceedings of a Symposium honoring Douglas W. Fuerstenau on his 60<sup>th</sup> birthday, Editors, K.V.S. Sastry and M. C. Fuerstenau, Society of Mining Engineers, Inc., Littleton, Colorado, 1989, incorporated by reference herein). Generally the energy to grind a solid to a specified particle size distribution has been 20 related to an index called the Bond Work Index. This is widely used. Values of the Work Index range generally for 1.4 for calcined clay to 135 for mica. Coal of specific gravity 1.63 has a reported index of 11.4 (Chemical Engineers Handbook, Fifth Edition, Edited by Robert H. Perry, and Cecil H. Chilton, McGraw- 25 Hill Book Company, New York, NY 1973, page 8-11, incorporated by reference herein). Those solids with a large Work Index require 30

more energy to grind to a given particle size. This means more time in the comminutor. Particles with lower Work Indices will require less time. The Work Index is a general measure of the tendency of hard to grind materials to concentrate in the internal circulation of comminution devices.

The value, 11.4, listed for coal is relatively high on this scale because coal of density 1.63 has a significant amount of mineral impurities which have higher work indices than does the mineral-free soft coal. Indeed, the grindability of coal is measured by an index which is different from the Bond Work Index. It is called the Hardgrove Grindability Index, (HGI) and is generally restricted to coal. HGI measurements are made when a specified particle size distribution of the coal is placed in a laboratory grinding machine of a standardized design and a specified amount of grinding energy is expended [See Steam, Its Generation and Use, Babcock & Wilcox, New York, NY, 1978, and Combustion Fossil Power Systems, A Reference Book on Fuel Burning and Steam Generation, Ed., Joseph G. Singer, Combustion Engineering, Inc., Windsor, CT 1981, incorporated by reference herein]. The amount of material in the product of grinding which is finer than 200 mesh (74 microns particle diameter) is compared with that of a standard coal whose HGI is taken as 100. On this scale, the higher the value, the more friable or easier the coal is to grind. The grindability of coal is a composite property made up of other properties, such as hardness, strength, and fracture for example. A general relationship exists between grindability and rank. Coals that are easiest to grind are found in the medium and low volatile groups. They are decidedly easier to grind than coal of the high volatile bituminous, sub-bituminous, and anthracite ranks. [See Coal Preparation, 4<sup>th</sup> Edition, Edited by Joseph W. Leonard, The American Institute of Mining, Metallurgical, and

Petroleum Engineers, Inc. New York, 1979, Page 1-8, incorporated by reference herein].

The effects of coal grindability on pulverizer throughput are described in combustion technology handbooks [See for example 5 Steam, Its Generation and Use, Chapter 9, "Preparation and Utilization of Pulverized Coal," Babcock & Wilcox, New York, NY, 1978, and Combustion Fossil Power Systems, A Reference Book on Fuel Burning and Steam Generation, Ed., Joseph G. Singer, Chapter 12, "Pulverizers and Pulverized-Coal Systems," Combustion Engineering, 10 Inc., Windsor, CT 1981, incorporated by reference herein]. The grindability is a function of moisture in the coal, its rank, petrographic makeup, and mineral content and types. The effects of petrographic makeup and minerals have not been generally been recognized or used. (R. R. Oder and R. J. Gray, "The Effects of 15 Coal Characteristics on Fine Grinding in a Pitt Mill, **Chapter 48**, in Comminution - Theory and Practice, S. Komar Kawatra, Editor, Society of Mining, Metallurgy, and Exploration, Inc. Littleton CO, 1992, incorporated by reference herein). Table I shows the effects of ash and sulfur levels on the HGI of a blend of medium and high 20 volatile bituminous rank raw coals being ground in an operating pulverizer in a pulverized coal fired power plant in North Central Pennsylvania. The "Pulverizer Concentrated Sample" is material withdrawn from the internal circulation of the pulverizer. It has significantly higher levels of ash and sulfur than the pulverizer 25 feed and a significantly lower value of HGI. The increased sulfur in the "Pulverizer Concentrated Sample" is caused by increased concentration of iron pyrite in the sample. The "Magnetic Separator Reject" material is reject material taken from the "Pulverizer Concentrated Sample" by a dry magnetic separator of the 30 type described in this patent. It is discarded from the pulverizer.

Table I. Effects of Ash and Sulfur Concentrations on HGI for a blend of North Central Pennsylvania Bituminous Coals Sampled at Various Points in a MagMill™

Sample	HGI	Ash	Sulfur
Pulverizer Feed	63	14.4	2
Pulverizer Concentrated Sample	58	33.6	11
Magnetic Separator Reject	57	48.7	9

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It is apparent that there are mineral impurities in the  
10 coal which can be removed from the internal stream circulating  
inside the pulverizer which have high concentrations of ash and  
sulfur and which adversely affect the grindability of the coal.

**Effects of Hard Particles on Power Consumption and Throughput of a  
Coal Pulverizer**

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Separation of the particles of high levels of ash and  
sulfur from the internal circulation of a pulverizer will increase  
the effective grindability of the particles in the grinding zone.  
This has the effect of increasing the throughput and reducing the  
grinding energy of the pulverizer. This has been observed in  
20 grinding an Upper Freeport seam coal from North Central  
Pennsylvania. The coal was ground in a nominal 1½ ton per hour  
(TPH) pilot ring/roller pulverizer. A nominal 1½ TPH prototype  
MagMill™ was made by retrofitting an ElectriMag™ and ParaTrap  
Magnetic separator of the type described in this patent to the  
25 pilot mill. Mill concentrated material taken from the base of the  
pulverizer was processed. The throughput of the MagMill™ prototype  
increased to 120% and the grinding energy reduced to 70% of that of  
the unmodified pulverizer processing the same coal when the iron  
pyrite content in the product of the MagMill™ had been reduced by

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nominally 70% and the ash level by 40% with respect to the coal fed to the MagMill™.

### Mill Wear

In general, the combination of hard materials, coarse particles, and high velocity are conducive to wear in mills. Extensive data on the wear and cost of various types of steels in ore grinding have been reported (Norman and Loeb, Trans. A.I.M.E., 183, 330, 1949, incorporated by reference herein). Mill wear or abrasion becomes critical on high-peripheral-speed equipment, particularly high-speed close-clearance hammer mills and coal pulverizers of the roller and bowl types low in the mill near the throat. An abrasion index in terms of kW-hr input/Lb of metal lost furnishes a useful indication. Rough values can be found in the Chemical Engineers Handbook, Page 8-10, 1973. Abrasive indices for the 38 materials shown range from 0.0001 for Sulfur, to 0.6905 for Quartzite. Coal is near the low end of the scale and most minerals in coal are near the high end.

**Abrasive Wear In Coal Pulverizers.** The abrasiveness of coal contributes to operating and maintenance costs at pulverized-coal fired power plants. Areas of high wear are areas inside the pulverizer where coarse particles of high concentrations of ash and sulfur are accelerated by high air velocity entering the mill. This is generally in the base. Abrasive wear is increased many times under the high contact pressure developed between coal and metal in pulverizers. It is important to recognize the relationship between high density coal components found in the lower portions of pulverizers and the wear they cause. This is illustrated in the results of abrasive wear tests made on Eastern US and a Western US raw bituminous rank coal and their specific-

gravity fractions which are shown in Table II. These tests show the relationship between the ash levels, abrasive wear, and the specific gravity fractions of the coals. The abrasiveness of raw coals is almost completely due to mineral impurities. [Excerpted  
 5 from Table 1-19, Coal Preparation, 4<sup>th</sup> Edition, Edited by Joseph W. Leonard, The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. New York, 1979, Page 1-51, incorporated by reference herein.]

Table II. Results of Abrasion Tests Made on Specific Gravity Fractions of Various Kinds of Coal

		Specific Gravity	Weight %	Ash %	Abrasion Loss, mg	Cumulative		
						Weight %	Ash %	Abrasion Loss, mg
Langley No. 9	Under	1.60	90.7	9.3	45	90.7	9.3	45
Christian Co., IL	Over	1.60	9.3	58.3	1515	100.0	13.8	181
Total Raw Coal							234	
Anthracite	Under	1.80	81.1	7.6	63	81.1	7.6	63
Schuylkill Co., PA	Over	1.80	28.9	71.8	2847	100.0	19.8	589
Total Raw Coal							686	
Cush Creek	Under	1.60	92.9	5.6	6	92.9	5.6	6
Indiana Co., PA	Over	1.60	7.1	62.1	351	100.0	9.6	12
Total Raw Coal							12	
Montour No. 10	Under	1.60	79.3	9.1	43	79.3	9.1	43
Allegheny Co., PA	Over	1.60	20.7	75.9	618	100.0	22.9	162
Total Raw Coal							172	
Castle Gate	Under	1.60	95.2	6.7	147	95.2	6.7	147
Carbon Co., UT	Over	1.60	4.8	63.7	1517	100.0	9.4	213

The abrasive wear attributable to coal is primarily related to the hardness of the minerals in the coal and especially to the quartz and iron sulfides, mainly iron pyrite. The hardness

is measured by empirical tests but is closely related to fundamental properties. It is a function of the rank of the coal and varies greatly among the maceral components. The hardness of coal is generally in the range 10-70 kg/mm<sup>2</sup> (Vickers Indentation Hardness Test). It has a maximum at 84% carbon (dry mineral free) and a minimum at 90% carbon (dry mineral free) and then increases again. By way of comparison, quartz and pyrite have Vickers hardness numbers of 1100-1260 and 840-1130 respectively and those of hard steels range from 600 to 700, [Coal Preparation, 4<sup>th</sup> Edition, Edited by Joseph W. Leonard, The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. New York, 1979, Page 293, incorporated by reference herein.]

SUMMARY OF THE INVENTION

The present invention pertains to an apparatus for sorting particles. The apparatus comprises a first comminution mechanism for releasing particles encases in a solid matrix. The apparatus comprises a first separating mechanism for removing particles from the comminution mechanism. The apparatus comprises a size classification means for separating particles based on their size. The first separating mechanism is engaged with the comminution mechanism and the size classification mechanism. The apparatus comprises a first magnetic means for separating particles with a magnetic force. The apparatus comprises an electric mechanism for separating particles with an electrical force disposed adjacent to the magnet mechanism. The apparatus comprises a first providing mechanism for providing particles to the electric and magnetic separation means. The first providing mechanism is engaged with the size classification mechanism and the electric and magnetic separation means. The apparatus comprises a second magnet mechanism for separating the less magnetic particles separated in the first magnetic mechanism. The apparatus comprises a second

mechanism for providing the particles to the second magnet mechanism. The second providing mechanism is engaged with the first and the second magnet mechanisms.

The present invention pertains to a method for sorting  
5 particles. The method comprises the steps of comminuting the  
particles to release particles encased in a solid matrix. Then  
there is the step of separating the particles from the comminuting  
device based on the hardness of the particles. Then there is the  
step of classifying these particles based on size. Then there is  
10 the step of charging the undersize particles by contact or by  
friction and of providing the particles to a first magnet mechanism  
and electric mechanism disposed adjacent to the magnet mechanism.  
Then there is the step of separating the particles with the  
magnetic force from the magnet mechanism and the electric force  
from the electric mechanism. The method also comprises the steps  
15 of providing the less magnetic particles separated in the first  
magnetic mechanism to a second magnet mechanism. Then there is the  
step of separating the less magnetic particles with the magnetic  
force from the second magnet mechanism.

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BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings, the preferred embodiment of  
the invention and preferred methods of practicing the invention are  
illustrated in which:

Figure 1. Schematic representation of a MagMill™.

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Figure 2. Schematic representation of the grinding  
chamber of a ring roller mill.

Figure 3. Schematic representation of the air entrance to the base of a ring roller mill showing screw conveyor.

Figure 4. Schematic representation of a static classifier with sampling apparatus attached.

5 Figure 5. Schematic representation of an explosion proof gate valve.

Figure 6. Schematic representation of a kick-out door mechanism.

10 Figure 7. Schematic representation of an alternative kick-out door mechanism.

Figure 8. Perspective view of an electric and magnetic separator.

Figure 9. View of magnetic flux lines in first stage permanent magnetic separator.

15 Figure 10. End view of receiving bin 1010 and perspective view of manifold plate 1100.

Figure 11. Perspective view of magnetic matrix.

Figure 12. Perspective view of electromagnet 1300 and magnetic matrix 1200.

20 Figure 13. Top view of electromagnetic separator with magnetic matrix in place.

Figure 14. Top view of electromagnet showing iron frame, matrix and coils.

Figure 15. Plan view of magnetic matrix showing drop areas for particles.

5 Figure 16. Perspective view of splitter mechanism.

Figure 17. Cutaway view of a MagMill™ employing a ring roller pulverizer.

Figure 18. Cutaway view of a bowl mill.

Figure 19. Cutaway view of a roller mill.

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#### DETAILED DESCRIPTION

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Referring now to the drawings wherein like reference numerals refer to similar or identical parts throughout the several views, and more specifically to Figure 1 thereof, there is shown a schematic representation of a MagMill™ pulverizer which consists of an air-swept pulverizer 1 and a separation means 2 working together. Raw feed 3 consisting of a plurality of particles of widely differing sizes with varying degrees of association enters the pulverizer 1 through the mill housing at 4. The largest particle is generally  $\frac{1}{8}$  inch to 1 inch in size. The feed can enter the mill from the top as well using means not shown. Air 5 is blown into the base of the mill through air scroll casing 18. Air and particles are conveyed out of the pulverizer at complete opening 6. A portion of the particles which are intermediate in size between that of the feed to the pulverizer and the product are removed from

the inside of the mill through removal mechanisms 7, 8, 9, and 10 at intermediate openings. These particles are conveyed 11 to surge bin 20 to the separation means 2. The oversize particles 15 can be conveyed either to the pulverizer for additional grinding 16 or 5 conveyed to reject 17 depending upon the quality of the particles. The product of the separation mechanism is returned to the pulverizer 16 for grinding to size specification. The reject from the separation mechanism is conveyed to refuse 17.

The grinding chamber 200 inside of the pulverizer is 10 shown in more detail in Figure 2. In the figure, 201 is a heavy stationary grinding ring. 202 is a rotating roller. The roller is suspended 203 from a rotating crossbar 204 cantilevered from a vertical centered drive shaft 205. Particles are pulverized by compression between the grinding ring 201 and the rotating rollers 15 202. One roller, 202, is shown in Figure 2. Mills may employ several rollers. A rotating plow, 206, cantilevered from the center shaft, throws the large, heavy particles which land near the center of the mill base back into the grinding zone between ring and rollers. Particles which are difficult to grind and which are too 20 heavy to be lifted by the air flow, 5, entering the mill base through air flow casing 18 and passing through a plurality of vanes 208 concentrate in the base of the pulverizer 207. Removal mechanism 7 passes through the air scroll casing 18. It opens to the base of the mill inside one the air flow vanes 208. A second 25 removal mechanism 8 enters the grinding chamber at 209 above the elevation of the rotating cross bar 204.

Hot air 5 is blown into the base of the mill 207 through the air casing 18 shown in Figure 3. Temperatures up to 250 to 350 degrees Fahrenheit can be used. The air is heated upstream of the air scroll casing by means not shown. The air enters the base of the mill with velocities ranging upward to several thousand feet per minute. The air swirls around the casing and enters the mill through vanes 208 opening underneath the grinding ring 201. The vanes direct the air flow tangential to the inside diameter of the grinding chamber 200. Removal mechanism 7 opens to the mill base in the grinding chamber through vane at 208. It is a screw conveyor of the type manufactured by AFC of Clifton, NJ. The separation mechanism may be located in any air inlet vane around the circumference of the pulverizer but preferentially is located away from the pulverizer inlet 4. The screw conveyor opens just inside the vane without protruding into the base where it would be hit by the plow. The air flow slot 301 immediately upstream of the screw conveyor opening is plugged off to prevent air flow. In operation, this permits buildup of particles in front of the screw conveyor. It is not necessary to employ an air lock device at the exit of the conveyor because air flow is blocked by particles inside the length of the conveyor. The screw conveyor mechanism must be able to operate at the temperature in the base of the pulverizer. More than one separation mechanism 7 may be used in the base of the mill.

The inside of the pulverizer at an elevation above the top of the gear train mechanism 211 is shown in Figure 4. The casing 400 encloses the inverted cone of a static classifier 401. Air and particles passing upward through the mill enter the classifier through vanes 402. Small particles and air exit the

pulverizer through the product pipe at 6. Oversize particles drop to the bottom of the inverted cone and return to the grinding chamber 200 through flap valves 403. A separation mechanism 9 is attached to the outside wall of the casing 400. It connects to the  
5 inside space between the casing wall and the inverted cone 401. A separation mechanism 10 passes through the casing 400 and is attached to the bottom of the inverted cone at the flap valves 403.

Separation mechanism 8 is a kick-out door. It opens to  
10 the inside of the pulverizer chamber at 209. The separation mechanism 8 can be located at any elevation from the top of the roller 202 up to the top of the grinding chamber at 210. It is preferentially at an elevation above or below the rotating arm 204 and at a location around the circumference of the grinding chamber  
15 which is away from the feed 4 and the mill drive shaft 212. More than one separation mechanism 8 may be used in the grinding chamber.

Separation mechanism 9 is a kick-out door. It opens into  
the region of the pulverizer above the top of the gear train  
20 mechanism 211 between the casing 400 and the inverted cone 401 of the classifier. It can be located at any elevation from the top of the gear train mechanism 211 up to an elevation below the entrance to the classifier at 402. More than one separation mechanism 9 may be used above the top of the gear train mechanism. It can be  
25 located anywhere around the circumference of the classifier.

The kick-out door mechanism can be as shown in Figure 6 or Figure 7. The mechanism 700 shown in Figure 7 is attached to the

pulverizer through mill flange 701. The kick-out door 702 is hinged horizontally so that it opens into the volume of the pulverizer from the bottom edge of the chute 703. Particles which are falling downward inside the pulverizer would be deflected into 5 the chute 703 as shown. Lever 704 is used to open or close the kick-out door 701. The chute 703 is attached to air lock mechanism 705 through air-lock flange 706. The air lock of the type manufactured by W. M. Meyer & Sons, Skokie, IL, can be operated manually or continuously. The kick-out door mechanism can be 10 hinged horizontally so as to open horizontally from the top or the bottom of the chute or it can be hinged vertically from the left or the right side of the chute so as to open clockwise or counterclockwise as seen from above.

When there is no potential for explosion both kick-out 15 door mechanisms 8 and 9 are attached directly to the pulverizer as shown in Figure 7. When there is a danger of explosion or of fire, the kick-out door mechanism is attached to the pulverizer through an explosion proof gate valve 500 shown in Figure 5. The gate valve is welded to the side wall of the grinding chamber. With the 20 slide 501 pulled out, the inside of the pulverizer is reached through the opening 502 in the center of the gate valve frame 503. The slide 501 slides in the trough 504. The explosion proof gate valve is designed to withstand pressures of 50 psi.

A second mechanism 600 for removing particles from the 25 inside of the pulverizer is shown in side view in Figure 6. The mechanism is mounted to the side of the pulverizer 601 through explosion proof gate valve 500. The sampling device consists of a

rectangular chamber 604 which is mounted to a flange 602 for attachment to the gate valve on the side of the pulverizer. The flange makes an angle of approximately 60 degrees with respect to the vertical. The gate valve 500 can be attached directly to the  
5 side of the pulverizer or can be attached to access doors on the side of the pulverizer using a transition plate 603. The transition plate is a plate which is thick enough to withstand 50 psi excursions in the pressure and which is used to accommodate the difference in the bolt hole locations on the gate valve 500 and  
10 those on the pulverizer. The chamber 604 contains a sampling device 605 which is rectangular in cross section and which is open at end 606 and has an opening in one wall at the other end 607 as shown in the Figure. A rod 608 is attached to the inside face of the sampling chamber at 613. This rod passes through the vertical  
15 wall at the back of the sampling mechanism at 609. A dustless connector 610 consisting of a cylindrical hollow fibrous plug surrounding the rod 608 and fitting inside a cylindrical sleeve 614 prevents dust leakage from the inside of the pulverizer. The rod 608 is used to move the sampling device 605 into and out of the  
20 pulverizer. The sampling device can be arranged to open up, as shown in Figure 6, or to open down. Flange 611 connects the sampling device 600 to an air lock mechanism 612 for isolating the material being taken from the mill.

Particles removed from the pulverizer by separation  
25 devices 7, 8, 9, or 10 can be issued to reject stream 17 directly or conveyed 11 to feed hopper 20. The particles withdrawn from the internal circulation in the mill by any of the sampling mechanisms, 7, 8, 9, or 10 can be directed individually or in combinations to

the reject stream 17. The conveyance mechanism 11 can be a screw conveyor or a conventional conveyor of the type manufactured by AFC of Clifton, NJ. The conveyance mechanism 11 and the separation mechanism 2 and return conveyance mechanism 16 and the reject 5 conveyance mechanism 17 should be enclosed to prevent dusting. The capacity of the conveyors 11 ranges from 1/10 to the full rate at which particles are fed to the pulverizer and preferentially is in the range of 1/3 to  $\frac{1}{2}$  of the full rate of the feed. The capacity of the return conveyance devices 16 and the reject conveyance 10 mechanism 17 ranges from 1/6 to the full rate of the feed to the pulverizer.

Particles are issued from feed hopper 20 to classifying screen 12. Oversize particles 15 generally coarser than 3 mm or 8 mesh taken from classifying screen 12 are conveyed to switch 19. 15 The switch can divert the oversize particles back to the pulverizer through stream 16 or can discharge them to reject through stream 17, depending upon quality of the particles. The underflow at classifying screen 12 is conveyed to vibrating feeder 100 and thence to the electric and magnetic separator 13.

20 The following description refers to Figure 8. Particles in the size range from .07 mm to 3 mm discharge onto a vibratory feeder 100 of the type which can be obtained from Eriez Magnetics, Erie, PA, such as Model No. 15A. The surface of the vibratory feeder 100 is made of a conducting material which has a work 25 function which is intermediate between those of the particles to be separated. For example, in sorting coal particles containing mineral impurities copper may be used. The vibrating tray serves

as a means to triboelectrically charge the particles and to move them to the surface of a belt conveyor 801. Particles with the lowest work function will generally become positively charged and the particles with greatest work functions will become negatively charged. The particles pass under a permanent magnet 802 as they fall onto the belt. The permanent magnet serves to remove strongly magnetic gangue material such as shards of iron which may be in the mixture of particles. The particles are further charged by sliding friction as they fall onto moving belt 801. The belt carries the particles to the magnetic pulley 803 at the end of the belt conveyor. The belt can be made from insulating, or conduction material and can have iron fibers implanted in the surface to enhance the magnetic field gradient at the surface of the magnetic separator 803. Preferably the belt is made from antistatic material such as can be purchased from Taconic, Petersburgh, NY.

A vertical section through the center of magnetic pulley 803 is shown in Figure 9. The permanent magnet separator is composed of a cylindrical arrangement of permanently magnetized elements 900 made from materials such as Samarium Cobalt or Neodymium-Iron-Cobalt which are separated by magnetic steel spacers 901. The permanent magnets are magnetized along their cylindrical axes and are arranged so that the magnetization 902 of each opposes that of the other all along the axis of the cylinder. In this fashion, the magnetic flux emerging over the faces of adjacent magnets is oppositely directed. The opposing fluxes 903 at faces 904 and 905 are conveyed outward along the radius of the cylinder through the steel spacers and emerge transverse to the surface of the steel spacers at 906 thus producing regions of highly divergent magnetic fields reaching outward from the surface of the permanent

magnet which serve as capture sites for magnetic particles. The magnetic flux is returned to the magnet at regions 907.

Particles which migrate to the regions of high magnetic flux such as 906 and 907 and which are held there by magnetic forces at the surface of the belt are carried around the axis 908 of the pulley 803 by the belt 801 and drop free from underneath the belt at 804 as the belt pulls away from the cylindrical magnet surface. A doctor blade 807 is located at the back edge of the idler pulley 808 to remove particles adhering to the belt.

An electrode 809 is placed adjacent to the belt magnetic separator 13 as shown in Figure 8. It can be adjusted to be a few millimeters from the surface of the particles on the belt and as much as a few centimeters. It is located so that particles deflected outward from the separator by electric and inertial forces can pass underneath the electrode and reach the receivers 816 and 817. The electrode is energized by voltage source 810. The voltage applied to the electrode generates an electric field at the surface of the permanent magnet 803 which permanent magnet is made part of the electrical circuit. The electric field can range from a few hundred volts per centimeter up to the breakdown strength of air. It is preferentially in the range of 1000 to 5000 volts per centimeter.

A catch basin 101 is located underneath the belt separator 13 to collect particles as they are thrown from the belt separator. The catch basin can be made from conducting or insulating materials. Non-conducting materials are preferred since there is less interaction with the applied electric field.

Particles collected in the receivers which are farthest from the magnet **803** are the least magnetic and have electric charge similar to that of the surface of the magnet. These particles are expelled to the weakly magnetic product through the chute **806**.

- 5 Particles which are charged oppositely to the surface of the magnet and which are the most magnetic will be collected at **818**. They are expelled through chute **804**. Particles with intermediate magnetism and with weak or no surface charging will be collected at **816**. They constitute a middling fraction which is processed in the  
10 second magnet mechanism **14** for additional magnetic separation. These particles are expelled through chute **805** into magnetic separator **14**.

Particles exiting the first electric and magnetic separator at **805** fall into a receiving bin **101** shown in end view in  
15 Figure **10**. Particles are fed from bin **101** into the second magnetic separator **14**. The bin can be made from a conducting or a non-conducting material. It is preferentially made from non-conducting material so as not to interfere with the electric fields produced by the first stage electric and magnetic separator. Bin **101** has  
20 sloped sides **1000** and has a divider **1001** running along its length to partition the bottom into two regions of equal area. Each of the two regions **1002** opens into a series of rectangular openings **1101** in the manifold plate **1100**, which forms the bottom of bin **101**. The manifold plate is aligned with and attached to the magnetic  
25 matrix **1200**, shown in perspective in Figure **11**, located inside the working volume of the transverse access electromagnet **1300** shown in Figure **12**. The manifold plate **1100** has openings **1101** in its upper surface which communicate with openings **1201** between the poles **1202**

of the magnetic matrix. Poles 1202 are half-cylinders. The manifold plate 1100 has openings 1102 at either end under the divider and along each side between the openings 1101 for the purpose of admitting air into the magnetic separator along with the 5 particles. The particle flow drags air so that the air and coal are balanced as the particles enter the region 1201 between poles 1202. Without the openings 1102, the coal could draw air into the separation chamber in a non-balanced manner and disrupt the flow through the separator.

10           The magnetic matrix 1200 is magnetized by the surrounding transverse access electromagnet 1300 and is an integral part of the magnet circuit. (The electromagnet 1300 is shown in top view in Figure 13 with the magnetic matrix removed.) It is shown in top plan view in Figure 14 with the magnetic matrix installed. The 15 design for the electromagnet of this invention is an iron encased split solenoid with transverse access. Both the coil 1301 and the iron 1302 surround the working volume so both contribute to the field there. As is apparent in Figure 14, both the electromagnet coil and the magnetized iron contribute to the magnetic field which 20 magnetizes the separation matrix.

          The transverse access electromagnet shown in Figure 12 has two saddle-shaped coils 1301. They are inserted in the working volume of the magnet frame and each is folded outward at the top and the bottom of the magnet to permit transverse access. This 25 opens the working volume inside the electromagnet between the coils. The separation matrix 1200 shown removed from the magnet in

Figure 12 is placed in the working volume between the coils 1301 when in operation.

A plan view of the top of the electromagnet 1300 with the magnetic matrix 1200 removed is shown in Figure 13. The iron yoke 5 1302 is a rectangle with rectangular shaped hollow center. The iron frame can be cast or can be made from separate pieces which are bolted together. The iron frame is preferably made from annealed cast iron, 1002, 1006, or 1008 carbon steel or better. The width of the walls and the height of the iron frame is made great enough 10 to conduct the magnetic flux generated by the current in the energizing windings.

Looking from above in Figure 13, the individual coil windings rise up and out of the plane of the figure at the top and return into the plane of the figure at the bottom. They are 15 comprised of two saddle shaped coils 1301. Each is folded outward on the upper and lower magnet surfaces to allow access transverse to the direction of the magnetic field which is directed from left to right in the plane of the drawing. The electric current is 20 directed out of the plane of the paper in the upper portion of each coil and is directed into the plane of the paper in the lower portion of the coils. The current coming up in the upper coils flows horizontally outward on the top of the magnet through the coils which have been folded over and returns through the windings 25 in the lower portion of the figure. This produces a magnetic field directed to the right in the horizontal plane of Figure 13.

One end of the windings 1403 is shown in the left portion of the figure, the other 1404 in the right portion. Current connections are made at these ends to an external power supply (not

shown) such as that supplied by Electronic Measurements, Inc., Neptune, NJ. The coil windings are made from copper or other suitable conductor and can be hollow to accommodate cooling. Connections are also made at these endings for cooling water 5 supplied by a chiller (not shown) such as that supplied by Affinity Inc., Ossipee, NH.

Referring now to Figure 15, there is shown a plan view of a magnetic matrix 1200 which consists of two columns of poles which 10 columns are divided into groups of four pole pairs each. Particles are introduced at the top of the matrix into the rectangular regions 1806 between poles and fall along the length of the poles to an exit at the bottom. The pole length is chosen to give sufficient residence time for separation which occurs in the plane 15 of the figure. For processing coal, the pole length can be from 4 inches to 12 inches and is preferentially 9 inches. The residence time for particles falling through the matrix is a fraction of a second.

The weakly paramagnetic or diamagnetic particles in the stream of particles entering at 1806 are pushed by magnetic forces 20 outward into the regions 1802 where the magnetic field strength is lowest. Paramagnetic particles are attracted and trapped in the regions 1803 near the pole tips. The magnetic force is sufficient to separate the particles but not strong enough for particles exiting the first electric and magnetic separator at 805 to stick 25 to the poles in the magnetic separator 14. The particles which pass generally have magnetic susceptibilities less than about  $5 \times 10^{-9}$  m<sup>3</sup>/kg.

Shown in Figure 15 are magnetic rods 1805 which are

affixed to the faces of the poles 1801. The rods serve to increase the local magnetic field in the region immediately adjacent the pole tips. This has the effect of reducing the volume between poles in which the magnetic force is small. Preferentially, the 5 diameter of the steel rod is 1% to 10% of the diameter of the matrix pole and more preferentially 4%.

In the bottom portion of Figure 15 is shown a top view of knife edge splitters 1901 located underneath the bottom of the matrix 1200. These splitters divide the stream of particles 10 exiting the magnetic separator into separate streams based on the magnetism of the particles. The splitters can be adjusted as shown in Figure 16 so as to vary the area open between each.

Referring now to Figure 16, a splitter mechanism 1900 of the type described in US Patent No. 5,017,283 (May 21, 1991), 15 incorporated by reference herein, is shown in exploded view. The mechanism 1900 is assembled using end plates 1906 and is aligned with the exit of the splitter and supported independently. Each splitter 1901 is hinged at the bottom so that it can be rotated from the vertical. In this way, the top opening between vanes can 20 be adjusted individually or collectively. The bottom opening between hinges 1902 is fixed and is approximately  $\frac{1}{4}$  of the width of each pole pair which is twice the diameter of the poles 1801.

The particles collected in adjacent openings 1903 between splitters have different magnetic susceptibilities. Referring now 25 to Figure 15 each opening for collection of diamagnetic particles 1850 will be sandwiched between two openings for collection of

paramagnetic particles 1860, except at the opposite ends of the magnetic matrix, each of which will collect diamagnetic particles.

Particles exiting at the bottom of splitter 1901 fall directly into chute mechanism 1904. Each segment 1906 of this 5 mechanism has a ramp 1907 which directs the falling particles laterally out of the separator through holes 1905. The ramp in each adjacent segment is sloped oppositely so that all particles of like magnetism exit the separator on the same side. Paramagnetic particles will be on one side and diamagnetic particles will be on 10 the other.

The composite stream of diamagnetic particles is discharged through chute 815 of Figure 8. It is combined with diamagnetic or weakly paramagnetic particles separated from the first electric and magnetic separator and expelled through stream 806. The composite stream of diamagnetic or weakly paramagnetic particles is expelled through chute 814 to stream 16. The composite stream of paramagnetic particles exiting magnetic separator 14 exits the separator in stream 813. It can be combined with the stream of strongly paramagnetic particles exiting the 20 first electric and magnetic separator 804 to make stream 17. The width of the collection chambers can be adjusted through hinged baffles 1905 - 1902 which can be rotated to change relative recoveries of paramagnetic and diamagnetic particles. Increasing the width of the collection chamber for diamagnetic particles and 25 decreasing that for paramagnetic particles will increase the diamagnetic particle weight recovery and decrease the quality of the diamagnetic particle product and vice versa. It is apparent that the system of splitters can be used to separate particles of

any type of magnetism. It is not restricted to paramagnetic and diamagnetic particles only.

The weakly magnetic particles exiting the first electric and magnetic separator at 806, the diamagnetic particles exiting 5 the second magnetic separator at 815, the paramagnetic particles exiting the second magnetic separator at 813, and the strongly magnetic particles exiting the first electric and magnetic separator at 804 can each be collected separately or can be combined as desired.

Figure 1 and the description which follows it illustrates a preferred embodiment of this invention. The air-swept pulverizer used for illustration is of the ring/roller type such as that manufactured by Bradley Pulverizer Company of Allentown, Pennsylvania. While the grinding mechanism employed is that of a ring/roller mill, all other mills for which particles circulating inside the mill can be accessed, such as hammer mills and roller mills, can be used. The classifier oversize material which is returned to the grinding zone from pulverizers such as ball mills 20 can also be treated by the method of this invention. The method described above can be used in pulverizers employing under pressure or over pressure. Further the preferred separator means including size classification and magnetic separation are illustrative of the invention and are not intended to be limiting. Other mean of 25 separation can be employed such as size classification alone, or magnetic and electric separation, cyclones, air tables, etc.

Referring now to Figure 18, there is shown a cut-away view of a bowl mill 2100 such as a Model 633 made by CE Raymond. This is an air-swept pulverizer. Particles are fed down the center

- pipe 2111 onto a bowl shaped grinding table 2103. This bowl is rotated from below by drive shaft 2112. Air is blown into the base of the mill through inlet 2113 and swirls upward into the grinding chamber 2108 through a narrow throat opening between the outside of 5 the bowl 2103 and the inside wall of the mill. Because of the narrow opening at the throat the air velocities are thousands of feet per minute, typically 7000 feet per minute. Particles landing on the surface of the bowl are slung outward by rotation and are ground as the table rotates underneath the grinding rolls 2114.
- 10 Particles are splashed and swept in all directions inside the mill as they are released in the grinding action on the bowl. Heavy particles fall back to the table and are ground further. Particles are swept upward by the swirl of air 2109. Some particles are thrown outward hitting the inside wall of the mill as they travel upward. These particles fall back to the bowl for additional 15 grinding. Other particles are conveyed to the top of the mill and enter the classifier 2102 through the vanes 2115. The finest of the particles are discharged from the mill through the pipe 2110. Oversize particles fall to the bottom of the inverted cone of the 20 classifier 2102 and are mixed with the feed particles at 2116 and thence discharged to the bowl 2103.

This pulverizer is different from the ring/roller in that a rotating bowl and stationary roller are employed as opposed to rotating rollers and a stationary ring. Further, this mill has a 25 mechanism 2107 for discharging large pieces of very hard particles such as machine parts and railway spikes from the grinding zone in order to protect the mill. In grinding coal this is called a pyrite trap. Particles which are small enough to pass through the vane openings in the throat and which are heavy enough to fall

under the air drag in that region will discharge underneath the bow and be swept by scrapers 2106 to the discharge chute 2107. When grinding coal, the rate at which particles emerge through the pyrite trap is very small, about 0.1 % of the rate at which 5 particles are fed to the pulverizer. This discharge mechanism is designed to protect the mill and not to improve the quality of the mill product.

Contrary to the pyrite traps, the MagMill™ is designed to remove large amounts of the particles circulating inside the 10 mill. These particles are removed and processed external to the mill so as to improve the quality of the mill product. Withdrawal rates between 10% and 100% of the rate of feed to the mill and preferably 30% to 50% are employed.

A mechanism for removing mill concentrated material from 15 the internal circulation of the mill is shown at 2101. This mechanism is of the types shown in Figures 3, 6, and 7. Figure 3 shows a screw conveyor. This can be used to separate particles from the surface of the bowl or from the return from the classifier at 2116. Particles have been withdrawn from pulverizers at the 20 rate of 1 ton per hour through 3-inch opening screw conveyors of the type manufactured by AFC of Clifton, NJ. Multiple screw conveyors can withdraw significant amount of particles from pulverizers.

Figures 6 and 7 illustrate two mechanisms for removing 25 particles moving near the walls of the mill. The mechanism of Figure 6 can open at the wall of the mill or can extend several inches inside. The mechanism of Figure 6 has removed particles from CE Raymond 633 and 823 mills at rates ranging from 1 TPH per

Square Foot of opening up to 7.3 TPH per Square Foot of opening. The opening in square feet required to achieve the preferred withdrawal rate of 30% of the feed is about 0.05 times the rate at which the mill is fed. For a 50 TPH pulverizer, an opening in the 5 mill wall of 1.5 feet on a side will handle this amount of material. In order not to disrupt the flow inside the mill, several smaller withdrawal mechanisms would be employed located around the circumference of the mill.

Particles withdrawn from the pulverizer by mechanisms 10 **2101** can be either issued to reject stream **17** directly or conveyed 15 **11** to separation mechanism **2** as shown in Figure 1. The separation mechanism used here is exactly the same as that discussed above for the case of the ring/roller mill. The particles to be returned to the pulverizer from separation mechanism **2** can be returned through the wall of the pulverizer at **2198** or preferably through the feed chute **2111**. An air lock mechanism **612** of Figure 6 or **705** of Figure 20 **7** is employed to isolate the atmosphere inside the mill from that in the separation mechanism **2**. Reject particles are discharged from the pulverizer and separation mechanism into stream **17** of Figure 1.

Referring now to Figure **19**, there is shown a cut-away view of a roller mill **2200** such as a Model MPS-89 made by Babcock & Wilcox. This is an air-swept pulverizer. Particles are fed down the center pipe **2211** onto a grinding table **2203**. The table is 25 rotated from below by drive mechanism **2212**. Air is blown into the base of the mill through inlet **2213** and swirls upward into the grinding chamber through a narrow throat opening **2208** between the

outside of the table 2203 and the inside wall of the mill. Because of the narrow opening at the throat the air velocities are thousands of feet per minute, typically 7000 feet per minute. Particles landing on the surface of the table are slung outward by 5 rotation and are ground as the table rotates underneath the tires 2214. There is a groove on the table surface which guides the tires. Particles are splashed and swept in all directions inside the mill as they are released in the grinding action on the table. Heavy particles fall back to the table and are ground further.

10 Particles are swept upward by the swirl of air 2209. Some particles are thrown outward hitting the inside wall of the mill as they travel upward. These particles fall back to the table for additional grinding. Other particles are conveyed to the top of the mill and enter the classifier 2202 through the vanes 2215. The 15 finest of the particles are discharged from the mill through the pipes 2210. Oversize particles fall to the bottom of the inverted cone of the classifier 2202 and are discharged through flap valves 2216 to the table 2203.

This pulverizer is different from the ring/roller in that 20 a rotating table and stationary tires are employed as opposed to rotating rollers and a stationary ring. Further, this mill has a mechanism 2207 called a pyrite trap for discharging large pieces of very hard particles such as machine parts and railway spikes from the grinding zone in order to protect the mill. Particles which are 25 small enough to pass through the vane openings in the throat and which are heavy enough to fall under the air drag in that region will discharge underneath the table and be swept by plows 2206 to the discharge chute 2207. When grinding coal, the rate at which particles emerge through the pyrite trap is very small, about 0.1 30 % of the rate at which particles are fed to the pulverizer. This

discharge mechanism is designed to protect the mill and not to improve the quality of the mill product.

Contrary to the pyrite traps, the MagMill™ is designed to remove large amounts of the particles circulating inside the mill. These particles are removed and processed external to the mill so as to improve the quality of the mill product. Withdrawal rates between 10% and 100% of the rate of feed to the mill and preferably 30% to 50% are employed.

A mechanism for removing mill concentrated material from the internal circulation of the mill is shown at 2201. This mechanism is of the type shown in Figure 3. Figure 3 shows a screw conveyor. This can be used to separate particles from the edge or the surface of the table, from the groove in which the tires roll, or from the return from the classifier at 2216. Particles have been withdrawn from pulverizers at the rate of 1 ton per hour through 3 inch opening screw conveyors of the type manufactured by AFC of Clifton, NJ. Multiple screw conveyors can withdraw significant amount of particles from pulverizers.

Yet another mechanism 2299 for removing particles from the pulverizer is shown in the Figure. This mechanism is of the types shown in Figures 6 and 7 and is used for removing particles moving near the walls of the mill. The mechanism of Figure 6 can open at the wall of the mill or can extend several inches inside. The mechanism of Figure 6 has removed particles from MPS-89 mills at rates ranging upward to 7.3 TPH per Square Foot of opening. The opening in square feet required to achieve the preferred withdrawal rate of 30% of the feed is about 0.05 times the rate at which the mill is fed. For a 50 TPH pulverizer, an opening in the mill wall

of 1.5 feet on a side will handle this amount of material. In order not to disrupt the flow inside the mill, several smaller withdrawal mechanisms would be employed located around the circumference of the mill.

5 Particles withdrawn from the pulverizer by mechanisms  
2201 and 2299 can be conveyed directly to reject stream 17 or  
conveyed 11 to separation mechanism 2 as shown in Figure 1. The  
separation mechanism used here is exactly the same as that  
discussed above for the case of the ring/roller mill. The  
10 particles to be returned to the pulverizer from separation  
mechanism 2 can be returned through the wall of the pulverizer at  
2298 or preferably through the feed chute 2211. An air lock  
mechanism 612 of Figure 6 or 705 of Figure 7 is employed to isolate  
the atmosphere inside the mill from that in the separation  
15 mechanism 2. Reject particles are discharged from the pulverizer  
and separation mechanism into stream 17 of Figure 1.

The MagMill™ shown in cut-away view in Figure 17 employs  
a comminution device 1 and associated dry magnetic separator means  
2 for improving the quality of the output of the comminutor. In a  
20 MagMill™ pulverizer the particles which are reduced to product  
fineness, nominally 70 to 80% finer than 75 microns top size, will  
exit the mill as product 6 and are blown directly to the downstream  
processing. In a conventional pulverizer, all particles which  
enter the mill will eventually exit at 6. In a MagMill™ not all  
25 particles exit in stream 6. Particles exiting at the top of the  
pulverizer at 6 are the more friable particles in the feed. The  
hard particles are separated from the more friable particles and  
rejected from the mill in stream 17. Thus, unlike at conventional

pulverizer, a MagMill™ makes two products. Particles inside the pulverizer which are coarser than the product specification are returned to the grinding zone as part of the mill internal circulation **2001**. These are the less friable particles in the mill  
5 feed and are generally hard and abrasive. These particles concentrate in the oversize fraction of the internal circulation. For coal, these are ash-forming minerals, especially iron pyrites. These hard particles are further separated from the bulk of the particle flow inside the mill by weight, inertial forces, and air  
10 flow resistance. They are found primarily in regions of low elevation in the pulverizer. In the upper regions, these particles tend to be located near the inside walls of the pulverizer. The hard particles are both concentrated and first separated inside the pulverizer.

15           A portion of the hard particles are withdrawn from the mill by particle sampling mechanisms **7, 8, 9, and 10**. Some types of conventional pulverizers such as roller mills separate large and very hard debris such as iron spikes from the grinding zone through openings in the air flow passages in the bottom of the pulverizer  
20 (not shown here). These openings are generally called pyrite traps. They remove a very small amount of material from the pulverizer, generally less than 0.1% of the feed. The pyrite traps are intended to protect the pulverizer from damage. They are not used to improve the quality of the product of pulverizing. In a  
25 MagMill™, material is removed from the inside of the pulverizer through sampling mechanisms **7, 8, 9, & 10** at a very high rate. This can be as much as 100% of the rate at which particles enter the mill. Preferably, it is between 10% and 100% of the feed rate. More preferably it is between 30% and 50% of the feed rate. The  
30 purpose of removing this material is to improve the quality of the product. The advantage of processing this stream of particles taken

from the internal circulation of the pulverizer is the extra mineral liberation in this stream. The particles are intermediate in size between the size of particles fed to the pulverizer and that issued in the product. Separation of particles in this stream  
5 is more efficient than treating the feed. Further, this stream of particles has a high concentration of the hard material to be removed so that the separation mechanism 2 can be smaller than that required to treat the entire stream. The MagMill™ is a technically and economically advantageous method for improving the quality of  
10 the pulverizer product.

Particles which are removed from the internal circulation of the pulverizer through sampling mechanisms 7, 8, 9, & 10 can be either issued to reject stream 17 directly or fed to the hopper 20 and screening device 12 where oversize particles 15 are withdrawn.  
15 The particles withdrawn from the internal circulation in the mill by any of the sampling mechanisms 7, 8, 9, or 10 can be directed individually or in combinations to the reject stream 17 when the quality of the particles does not warrant processing through separation mechanism 2. Oversize particles are those which are too  
20 coarse for effective treatment in the separation mechanism 2. They are generally coarser than 8 mesh or about 3 mm. The top-size is dependent on the characteristics of particles to be processed in the separation mechanism. Generally, strongly magnetic particles can be processed efficiently at a coarser size than can  
25 feebly magnetic particles such as coal. When grinding coal, pulverizer concentrated particles are generally smaller than 8 mesh with only a few percent finer than 100 mesh. If the oversize particles coarser than 8 mesh are highly concentrated in hard impurity particles, they are rejected to stream 17. Otherwise the  
30 oversize particles are returned to the pulverizer for additional

grinding through stream 16. Under size particles, generally finer than 8 mesh, are fed to the electric and magnetic means 2 where particles are separated on the basis of air drag, particle mass, surface charging, and magnetic characteristics. The less desirable 5 hard particles separated by separator 2 are rejected from the MagMill™ in stream 17. The friable particles recovered by the magnetic separator are returned to the pulverizer for grinding to specification in stream 16. For coal, separation of mineral gangue results in a pulverized-coal product which has lower concentrations 10 of ash, sulfur, and associated trace metals than the coal fed to the pulverizer.

The following description of the method is given in terms of pulverizing coal in a ring/roller mill. It illustrates the principles of separation in operation inside the mill and shows the 15 function of the electric and magnetic separator. While the grinding mechanism illustrated is that of a ring/roller mill, mills and crushers of other types could have been used and products coarser than pulverized are possible. Further, the separation mechanism shown is not limiting. Means for particle size 20 classification other than screening such as air classifiers, air tables, air cyclone, etc. can be used. Additionally, in some instances only the first stage ElectriMag Separator may be required.

Figure 17 is a cut-away view of a MagMill™ pulverizer 25 which consists of an air-swept ring/roller pulverizer 1 and a separation means 2 working together. Raw feed 3 consisting of a plurality of particles of widely differing sizes with varying degrees of association enters the pulverizer 1 through the mill housing at 4. The largest particle is generally  $\frac{1}{2}$  inch to 1 inch in

size. The feed can enter the mill from the top as well using means not shown. For coal pulverizing, the ash concentration of the feed coal may range from a few percent on a weight basis to 30 to 50 Wt.% or even higher while 7 to 10% is typical. The sulfur content 5 may range from below 1 Wt.% up to 5 to 10 Wt.% or even higher while 1 to 2% is typical. The MagMill™ 1 separates a mineral fraction, iron pyrite, which generally contains 50% of the sulfur in the coal. The concentration of the iron pyrite in the feed to the MagMill™ can range from less than 1 to 5 Wt.% or higher. It is 10 generally in the range from 0.5 to 1% Wt.%. Pre-combustion separation of iron pyrite will lower the sulfur oxide concentration in the combustion products which must be scrubbed and, perhaps more importantly, will reduce the amount of reactive iron sulfides at the water wall when low nitrogen oxide ( $\text{NO}_x$ ) burners are used. 15 Water wall wastage is related to reactive iron sulfides produced when iron pyrite is burned in low  $\text{NO}_x$  burners. The resulting sulfides migrate to the boiler walls and release sulfur which is very corrosive under the reducing conditions.

There are many trace metals in coal. Each can range from 20 parts per billion based on the weight of coal to thousands of parts per million. Of the trace metals, mercury, arsenic, and selenium are of particular interest because they are considered hazardous air pollution precursors (HAPS). Mercury is of particular interest because of the emissions restriction anticipated, less than 1 pound 25 of mercury per  $10^{13}$  Btu or approximately 1 pound of mercury  $10^9$  pounds of coal, and the difficult and cost of removal from flue gases, of the order of \$20,000 per pound of mercury. With mercury levels typically 100 pounds per billion pounds of coal, very high efficiencies of removal will be required. Arsenic is of additional 30 interest because this trace metal poisons catalytic reactors used for separation of nitrogen oxides from the combustion off gases. Catalyst replacement is very expensive.

Particles entering at 4 drop into the base of the pulverizer 207 where they are ground by being caught between the ring 201 and roller 202 mechanism. Particles are thrown in all directions by the energy release in the grinding event. The plow 206 revolves through the mass of particles in the base and moves these particles into the region between ring and roller. Large particles which strike the walls of the grinding chamber 200 fall back into the base of the mill where they are forced into the grinding mechanism again. Air 5 is blown into the base of the mill through air scroll casing 18. The upward swirl of air 2002 conveys particles in a swirling motion out of the grinding zone. Some particles are thrown outward against the inside wall of the pulverizer and fall back into the base of the mill where they undergo additional grinding. Small particles are conveyed upward in the pulverizer by the air flow 2002 and enter the classifier 2003 through vanes 402 at the top of the mill. The smallest particles are conveyed with the air flow out of the pulverizer at 6. Oversize particles which enter the classifier through vanes 402 are returned to the base of the mill through flap valves 403 at the base of the classifier.

A portion of the particles which are intermediate in size between that of the feed to the pulverizer and the product and which are in the base of the mill or are in motion above the grinding zone are removed from the inside of the mill through removal mechanisms 7, 8, 9, and 10. Mechanism 7 is a screw conveyor. Referring now to Figure 2, the mechanism 7 is shown passing through the air casing wall 18 and enters into the base of the mill 207 through the an opening in air flow vane 208. The end of the screw conveyor is open to particles. The air flow vane

slot upstream of the vane 208 is closed thus making a buildup of particles at the vane 208. These particles are removed by the screw conveyor and can be discharged to the reject stream 17 directly when the quality of the particles does not warrant 5 processing with separation mechanism 2 or transported to the separation mechanism 2 via the screw conveyor 11.

Particles colliding with or moving near the walls of the grinding chamber 200 are removed from the pulverizer through separation mechanism 8 mounted on the wall of the grinding chamber.

10 There may be more than one such separation mechanism and they may be mounted at various elevations above the top of the grinding zone in the base of the mill 207. The separation mechanism 8 opens into the mill through a hinged door which can be directed to catch particles which are rising, falling, or moving around the 15 circumference of the mill in either clockwise or counterclockwise direction. An air-jet mechanism 615 can be used to prevent excess amount of fine material from being withdrawn from the mill. This is accomplished by directing the air jet into the mill through the opening for mechanism 8. The coarse particles which are deflected 20 into the separation mechanism fall through an airlock mechanism which serves to isolate the atmosphere inside the mill. The mill can be of the overpressure or the under-pressure type. Particles exiting mechanism 8 can be discharged to the reject stream 17 directly when the quality of the particles does not warrant 25 processing with separation mechanism 2 or conveyed to the separation mechanism 2 via conveyor 11. This conveyor can be a screw conveyor, a belt conveyor, elevator or any method for moving the particles in the minus 8 mesh size fraction.

Particles which are falling along the inside wall of the outside casing of the classifier are removed from the pulverizer circulation by separation mechanism 9. More than one such mechanism may be employed and they may be mounted at any elevation 5 below the entrance to the classifier at the top of the mill. This mechanism may be arranged to catch particles rising, falling, or with a vortex motion in either direction around the inside wall of the classifier casing. Preferentially, it is arranged to catch particles falling back to the grinding zone. An air jet mechanism 10 615 similar to that described above can be used to prevent an excess of small particles from exiting the mill. The mechanism and the means to convey to the separation mechanism 2 or to the reject stream 2 are similar to that of separation mechanism 8.

A portion of the oversize particles exiting the bottom of 15 the classifier cone through flap valves 403 are conveyed through screw conveyor 10. They can be discharged to the reject stream 17 directly when the quality of the particles does not warrant processing with separation mechanism 2 or to the conveyance mechanism 11. These particles are close to final particle size but 20 have been recycled by the classifier because of their mass. They do not have excess ash and sulfur to the extent that oversize particles do which are low inside the pulverizer. The proportion of these particles which are separated from the mill will be dependent upon the necessity for complete treatment in the 25 separation mechanism. Generally, this stream may be neglected or treated only in small quantity.

Particles withdrawn from the pulverizer are conveyed 11. They can be discharged to the reject stream 17 directly when the quality of the particles does not warrant processing with

separation mechanism 2 or to the storage bin 20 at the input to the separation mechanism 2. Particles are discharged from bin 20 to the size classification means 12 which, for this example, is a screen. The undersize particles, generally smaller than 8 mesh, are 5 discharged to vibratory feeder 100. The oversize particles 15 can be conveyed either to the pulverizer for additional grinding 16 or conveyed to reject 17 depending upon the quality of the particles. The product of the separation mechanism is returned to the pulverizer 16 for grinding to size specification. The reject from 10 the separation mechanism is conveyed to refuse 17.

The vibratory feeder 100 serves to convey the undersize particles to the belt separator 801 and to electrically charge the particles by friction and contact. The material surface of the vibratory feeder is preferentially an electrical conductor which 15 has a work function which is intermediate between the two major types of particles to be separated. For coal, copper is preferred. In contact with copper, the hydrocarbon component of coal will lose an electron to the copper and become positively charged. The inorganic particles to be separated will generally acquire the 20 electron from the copper and become negatively charged. In addition to serving as an intermediary in the transfer of charge, the copper is an electrical conductor and this facilitates the charge transfer. The copper and inorganic particles do not have to be in direct contact to transfer the charge. The particles can 25 also transfer charge by direct contact.

The vibratory tray is also used to set the rate at which particles are issued to the belt separator. This is controlled by the motor action of the tray feeder.

Particles issuing from the vibratory feeder fall onto belt 801 which carries the particles to the magnetic separator 803. Further electric charging can occur as the particles contact the belt. Electric charge can be imparted to the particles. The belt 5 is electrically common with the surface of the permanent magnet 803. Triboelectric charging can occur when the particles skid on the surface of the belt. Skidding occurs when the horizontal component of the velocity of the particles falling from the vibratory tray feeder is different from that of the moving belt.

10 The belt material may be made from insulating or conducting materials and may have iron fibers implanted which will enhance the magnetic field gradient at the surface of the magnetic separator 803. The preferred belt is an antistatic belt which prevents buildup of electric charge on the belt. This is a belt of the type

15 manufactured by Taconic of Pittsburgh, NY.

A scalping magnetic separator 802 is suspended just above the belt surface at the exit of the vibratory tray feeder. This separator removes very strongly ferromagnetic particles from the stream of particles and prevents these particles from entering the 20 first magnetic separator 803.

An electrode 809 is suspended above the surface of the magnetic separator 803. A potential is applied to the electrode by source 810. The polarity of this electrode is chosen to be opposite of that of the surface of the magnetic separator which is 25 grounded. For processing coal, the electrode is negative with respect to the surface of the magnetic separator. The electric field is directed from the surface of the magnet to the electrode. In this fashion, positively charged carbon rich particles are attracted to the electrode and repelled by the magnetic separator.

Likewise, the minerals in coal are negatively charged and are attracted by both magnetic and electric forces to the surface of the magnetic separator. The electrode can be placed so as to support the separation. It can be at the end of the belt in front 5 of the magnetic separator or can be at any angle with respect to the horizontal from 0 degrees to 90 degrees. It must be placed far enough away from the surface of the belt so that particles which are lifted off the belt and deflected outward can reach the appropriate collector without hitting the electrode. Particles 10 which hit the electrode can be discharged and recharged so that they are driven back to the surface of the magnetic separator. This is undesirable. Potentials can be applied up to the breakdown strength of air.

Particles are thrown off of the belt separator 13 depending upon the balance of forces on the particles. First, any particle with an electric charge will have a mirror charge in the surface of the magnetic separator if the surface of the separator is an electrical conductor. This results in an electric field which can be directed away from the surface or toward it depending 15 upon the sign of the charge on the particles. Nonetheless, the resulting attractive force is always toward the surface of the magnet. Next, the applied electric field at the surface of the separator is directed normal to the surface and away from it. The net electric field is the vector sum of the mirror field and the 20 applied field. Negatively charged paramagnetic particles will be attracted to the belt while positively charged diamagnetic particles will be repelled if the applied field is greater than the mirror field.

The inertial force of rotation of the magnet is directed 25 away from the magnet surface. Gravity is everywhere directed

downward. A component of gravity directed toward the magnet surface will add to the attractive force in the upper 90 degrees of the motion around the end of the magnet and will subtract in the bottom portion of the arc. Once the particles leave the surface,  
5 air drag will tend to drag the particles into the magnetic fraction. The drag force will be greatest on the smallest particles in the stream. This is not expected to be important for particles generally greater than 100 mesh.

Negatively charged particles which are the most magnetic  
10 will travel around the arc of the first magnetic separator and will leave the belt underneath and away from the separator. They will generally have negative electric charges greater than  $-10^{-5}$  coulombs/kg and magnetic susceptibilities greater than  $10 - 50 \cdot 10^{-9} \text{ m}^3/\text{kg}$ . They will exit the first separator at 804.

15 Positively charged particles which are diamagnetic or the least magnetic will be thrown from the belt early in its travel around the magnet pulley. For coal, these particles will have magnetic susceptibilities generally less than  $10^{-9} \text{ m}^3/\text{kg}$  and may have electric charges generally greater than  $+10^{-5}$  coulombs/kg. They  
20 will exit the first separator at 806.

All other particles which have weak or no electric charge, generally between  $-10^{-5}$  and  $+10^{-5}$  coulombs/kg, and which are diamagnetic or very weakly paramagnetic with susceptibilities generally less than  $10 - 30 \cdot 10^{-9} \text{ m}^3/\text{kg}$ , will fall or be thrown from  
25 the belt near the leading edge of the magnetic pulley. They will exit the first magnetic separator at 805.

The particles exiting at 804 constitute the reject or refuse fraction. Those exiting at 806 are of product quality. The

other particles exiting at 805 are of intermediate quality. They can be reprocessed in the second stage electromagnetic separator 14 depending upon needs.

Particles exiting the first electric and magnetic separation means at 805 fall into catch basin 101 which feeds the particles to the second magnetic separation device 14. Referring now to Figure 10, basin 101 is an elongate bin with sloping sides. The bottom is divided along its length 1001 to separate the particles into two groups of equal mass. The particles in each of the two groups are fed through elongate rectangular openings 1002 spaced periodically along the bottom of the bin and aligned with openings of similar size in a manifold palate 1100 mounted on the top of the magnetic separation matrix 1200 located inside the working volume of the transverse access electromagnet. The bin serves to capture surges in the flow and to provide a uniform feed to the magnetic separator.

The manifold plate 1100 has two columns of elongate rectangular openings for admitting coal from the basin 101 into the open space shown in Figure 15 between flux convergers 1203 and the poles 1202 of the magnetic matrix 1200. The coal stream 1806 entering the void space has a rectangular shape.

Referring now to Figure 15, there is shown a plan view of a magnetic matrix 1200 which consists of two columns of poles which 25 columns are divided into groups of four pole pairs each. Particles are introduced at the top of the matrix into the rectangular regions 1806 between poles and fall along the length of the poles

to an exit at the bottom. The pole length is chosen to give sufficient residence time for separation which occurs in the plane of the figure. For processing coal, the pole length can be from 4 inches to 12 inches and is preferentially 9 inches. The residence 5 time for particles falling through the matrix is a fraction of a second.

The weakly paramagnetic or diamagnetic particles in the stream of particles entering at **1806** are pushed by magnetic forces outward into the regions **1802** where the magnetic field strength is 10 lowest. Paramagnetic particles are attracted and trapped in the regions **1803** near the pole tips. The magnetic force is sufficient to separate the particles but not strong enough for particles exiting the first electric and magnetic separator at **805** to stick to the poles in the magnetic separator **14**. The particles which 15 pass generally have magnetic susceptibilities less than about  $5 \times 10^{-9}$  m<sup>3</sup>/kg.

Shown in Figure **15** are magnetic rods **1805** which are affixed to the faces of the poles **1801**. The rods serve to increase the local magnetic field in the region immediately adjacent the 20 pole tips. This has the effect of reducing the volume between poles in which the magnetic force is small. Preferentially, the diameter of the steel rod is 1% to 10% of the diameter of the matrix pole and more preferentially 6%.

By way of example, when the pole tip diameter is 25.4 mm 25 and the width of pole gap is 8 mm, each pair of pole tip/convergers is capable of processing nominally 100 pounds of the weakly magnetic fraction of mill concentrated coal per hour. The matrix shown in Figure **15** has four such pole tip/converger pairs between

each divider 1204. Each of these groups handles nominally 400 pounds coal per hour. There are five groups in the matrix of Figures 11 and 15 so the matrix is capable of handling about 1 ton of the weakly magnetic fraction of mill concentrated coal per hour 5 when fully magnetized. This equates to a throughput of 13.6 tons of the weakly magnetic fraction of the mill concentrated coal per hour per square foot of available magnetized area transverse to the flow. By way of comparison, large high gradient magnetic 10 separators used in processing slurries containing 30 percent by weight of kaolin clay produce about 1.4 tons dry kaolin per hour per square foot of available magnetized area transverse to the flow.

As the coal particles accelerate downward through the open region between poles shown in Figure 15 the diamagnetic 15 particles will be pushed laterally into the regions of low magnetic field strength and the paramagnetic particles will be forced into the region of narrowest pole opening. The pole length must be great enough to accomplish the separation. This length has been determined to be 4 inches to 10 inches and preferably 9 inches when 20 processing the weakly magnetic fraction of mill concentrated coal particles.

In the bottom portion of Figure 15 is shown a top view of knife edge splitters 1901 located underneath the bottom of the matrix 1200. These splitters divide the stream of particles 25 exiting the magnetic separator into separate streams based on the magnetism of the particles. The splitters can be adjusted as shown in Figure 16 so as to vary the area open between each.

Referring now to Figure 16, a splitter mechanism 1900 of the type described in US Patent No. 5,017,283 (May 21, 1991), incorporated by reference herein, is shown in exploded view. Each splitter 1901 is hinged at the bottom so that it can be rotated 5 from the vertical. In this way, the top opening between vanes can be adjusted individually or collectively. The bottom opening between hinges 1902 is fixed and is approximately  $\frac{1}{4}$  of the width of each pole pair which is twice the diameter of the poles 1801.

The particles collected in adjacent openings 1903 between splitters have different magnetic susceptibilities. Referring now 10 to Figure 15, each opening for collection of diamagnetic particles 1850 will be sandwiched between two openings for collection of paramagnetic particles 1860, except at the opposite ends of the magnetic matrix, each of which will collect diamagnetic particles.

15 Particles exiting at the bottom of splitter 1901 fall directly into chute mechanism 1904. Each segment 1906 of this mechanism has a ramp 1907 which directs the falling particles laterally out of the separator through holes 1905. The ramp in each adjacent segment is sloped oppositely so that all particles of 20 like magnetism exit the separator on the same side. Paramagnetic particles will be on one side and diamagnetic particles will be on the other.

The weakly magnetic particles exiting the first electric and magnetic separator at 806, the diamagnetic particles exiting 25 the second magnetic separator at 815, the paramagnetic particles exiting the second magnetic separator at 813, and the strongly magnetic particles exiting the first electric and magnetic

separator at 804 can each be collected separately or can be combined as desired.

Figure 17 and the description which follows it  
5 illustrates a preferred embodiment of this invention. It is not restricted to pulverizing coal but can be used to improve the properties of any material for which size reduction will liberate the particle components and for which the size reduction mechanism serves also to concentrate one fraction while the separator  
10 mechanism serves to separate one fraction. The air-swept pulverizer used for illustration is of the ring/roller type such as that manufactured by Bradley Pulverizer Company of Allentown, Pennsylvania. While the grinding mechanism employed is that of a ring/roller mill, all other mills for which particles circulating  
15 inside the mill can be accessed, such as hammer mills and roller mills, can be used. The classifier oversize material which is returned to the grinding zone from pulverizers such as ball mills can also be treated by the method of this invention. The method described above can be used in pulverizers employing under pressure  
20 or over pressure. Further the preferred separator means including size classification and magnetic separation are illustrative of the invention and are not intended to be limiting. Other mean of separation can be employed such as size classification alone, or magnetic and electric separation, cyclones, air tables, etc.

25           Although the invention has been described in detail in the foregoing embodiments for the purpose of illustration, it is to be understood that such detail is solely for that purpose and that variations can be made therein by those skilled in the art without departing from the spirit and scope of the invention except as it  
30 may be described by the following claims.

WHAT IS CLAIMED IS:

1. An apparatus for separating undesired material from coal comprising:

an air swept pulverizer for breaking up coal into particles where the pulverizer is a hammer mill, bowl mill, roller mill, or ring/roller mill; and

a separation mechanism connected to the pulverizer for separating undesired material from coal.

2. An apparatus as described in Claim 1 wherein the pulverizer includes a feed mechanism which introduces coal into the pulverizer.

3. An apparatus as described in Claim 2 wherein the pulverizer includes an air blower which introduces flowing air into the pulverizer.

4. An apparatus as described in Claim 3 wherein the pulverizer includes a removal mechanism which removes undesired material and coal of an undesired size from the pulverizer.

5. An apparatus as described in Claim 4 wherein the separation mechanism includes a conveyor which carries undesired material and coal of an undesired size from the removal mechanism.

6. An apparatus as described in Claim 5 including a mechanism for returning cleaned coal from the separation mechanism back to the pulverizer for additional grinding.

7. An apparatus as described in Claim 6 including a mechanism for diversion of material removed from the pulverizer directly to refuse without going to the separation mechanism.

8. An apparatus as described in Claim 7 wherein the separation mechanism includes a surge bin disposed adjacent the conveyor into which the undesired material and coal of an undesired size is deposited from the conveyor.

9. An apparatus as described in Claim 8 wherein the pulverizer includes a grinding chamber.

10. An apparatus as described in Claim 9 wherein the pulverizer includes intermediate openings through which the removal mechanism removes undesired material and coal of an undesired size from the pulverizer.

11. An apparatus as described in Claim 10 wherein the pulverizer has a complete opening from which coal of a desired particle size leaves the pulverizer.

12. An apparatus as described in Claim 11 wherein the pulverizer includes a base and the removal mechanism includes a screw conveyor connected to the base.

13. An apparatus as described in Claim 12 wherein the pulverizer includes a particle size classifier.

14. An apparatus as described in Claim 13 wherein the cone includes kick-out door mechanisms through which material can be removed from the cone.

15. An apparatus as described in Claim 14 wherein the separation mechanism includes a screen disposed under the surge bin for screening material.

16. An apparatus as described in Claim 15 wherein the separation mechanism includes a vibrating feeder disposed under the screen on which material is deposited after passing through the screen.

17. An apparatus as described in Claim 16 including a mechanism for directly rejecting the oversize from the screen or sending back to the pulverizer.

18. An apparatus as described in Claim 17 wherein the separation mechanism includes an electric and magnetic separator disposed adjacent the vibrating feeder.

19. A method for providing coal of a desired particle size comprising the steps of:

producing a first stream of grindable particles and at least a second stream of particles with Hardgrove grindabilities at least 10% less than that of the first stream;

directing the first stream away from the pulverizer;

directing the second stream to a separation mechanism to further sort the second stream; and

returning to the pulverizer a desirable component separated from the second stream and rejecting an undesirable component.

20. A method as described in Claim 19 wherein the producing step includes the step of concentrating the particles with Hardgrove grindabilities at least 10% less than that of the feed particles in the pulverizer.

21. A method as described in Claim 20 wherein the producing step includes the step of producing the first stream primarily of coal of the desired particle size and producing the second stream primarily of ash-forming minerals.

22. A method as described in Claim 21 wherein after the second stream directing step, there is the step of returning the coal of low ash and low sulfur produced by the separation mechanism back to the pulverizer.

23. A method as described in Claim 22 wherein the ash-forming minerals include iron pyrite.

24. A method as described in Claim 23 wherein the producing step includes the step of introducing air flow with a blower into the pulverizer.

25. A method as described in Claim 24 wherein the second stream directing step includes the step of rejecting directly all the particles in the second stream.

26. A method as described in Claim 25 wherein the producing a second stream step includes the step of screening coarse particles from the stream of less grindable particles separated from the pulverizer.

27. A method as described in Claim 26 wherein the producing step includes the step of producing the first stream

primarily of coal of the desired particle size and producing the second stream primarily of minerals including mercury, arsenic and selenium.

28. An apparatus for separating undesired material from desired material of a mixture comprising:

a fluid swept comminutor for breaking up the mixture; and

a separation mechanism connected to the comminutor for separating undesired material from desired material.

29. An apparatus as described in Claim 28 wherein the comminutor includes a feed mechanism which introduces the mixture into the comminutor.

30. An apparatus as described in Claim 29 wherein the comminutor includes a fluid blower which introduces flowing fluid into the comminutor.

31. An apparatus as described in Claim 30 wherein the comminutor includes a removal mechanism which removes undesired material and desired material from the comminutor.

32. An apparatus as described in Claim 31 including a mechanism for direct rejection of material removed from the comminutor without further processing.

33. An apparatus as described in Claim 32 wherein the separation mechanism includes a conveyor which carries undesired material from the removal mechanism.

34. An apparatus as described in Claim 33 wherein the separation mechanism includes a surge bin disposed adjacent the conveyor into which the undesired material and desired material is deposited from the conveyor.

35. An apparatus as described in Claim 34 wherein the comminutor includes a grinding chamber.

36. An apparatus as described in Claim 35 wherein the comminutor includes intermediate openings through which the removal mechanism removes undesired material and desired material from the comminutor.

37. An apparatus as described in Claim 36 wherein the comminutor has a complete opening from which particles of a desired particle size leaves the comminutor.

38. An apparatus as described in Claim 37 wherein the comminutor includes a removal mechanism for separating particles from the lowest elevation in the comminutor.

39. An apparatus as described in Claim 38 wherein the comminutor includes a particle size classifier.

40. An apparatus as described in Claim 39 wherein the removal mechanism includes kick-out door mechanisms to remove material around the outside walls of the classifier at elevations above the grinding chamber but below the feed mechanism's entrance to the classifier.

41. An apparatus as described in Claim 40 wherein the separation mechanism includes a size classification mechanism disposed under the surge bin for screening material.

42. An apparatus as described in Claim 41 wherein the separation mechanism includes a vibrating feeder disposed under the screen on which material is deposited after passing through the screen.

43. An apparatus as described in Claim 42 including a mechanism for directly rejecting oversized material from the screen or sending it back to the pulverizer.

44. An apparatus as described in Claim 43 wherein the separation mechanism includes an electric and magnetic separator disposed adjacent the vibrating feeder.

45. An apparatus as described in Claim 44 including a mechanism for returning the desirable material from the separator back to the pulverizer and rejecting the undesirable material, the returning mechanism disposed adjacent the separator and the pulverizer.

46. A method for providing particles of a desired particle size comprising the steps of:

producing a first stream of particles and at least a second stream of particles with Bond Work Indices at least 10% higher than that of the first stream of particles with a comminutor;

directing the first stream away from the comminutor;

directing the second stream to a separation mechanism to further sort the second stream; and

directing the particles of lower Bond Work Indices back to the pulverizer and rejecting particles with Bond Work Indices of at least 10% higher.

47. A method for separating a mixture of coarse particles comprising the steps of:

feeding the mixture of coarse particles to a comminutor;

grinding the mixture to reduce particle size;

concentrating abrasive particles inside the comminutor;

removing the abrasive particles from the inside of the comminutor;

separating abrasive particles removed from the comminutor;

returning component with abrasion index 10% or less to the comminutor;

producing a product consisting of smallest particles which is enriched in less abrasive component, and

producing a second product consisting of intermediate size particles which are enriched in abrasive component.

ABSTRACT OF THE DISCLOSURE

METHOD AND APPARATUS FOR SEPARATING MATERIAL

An apparatus for sorting particles composed of a mixture of particles with differing physical and chemical characteristics. The apparatus includes a comminutor for reducing the size of the particles. The apparatus includes a mechanism for removing particles from the inside of the comminutor which are intermediate in size between the feed to the comminutor and the product of comminution. The apparatus includes a mechanism for either discharging particles taken from the comminutor to a reject stream or providing them to a size classification apparatus such as screening. The apparatus includes a mechanism for returning the oversize particles to the comminutor or for discharging them to the reject stream. The apparatus includes an electric mechanism for separating particles with an electrical force disposed adjacent to a magnet mechanism. The apparatus includes a mechanism for providing the particles to the magnet mechanism and the electric mechanism and for providing triboelectric and capacitive charges to the particles. The providing mechanism is engaged with the magnet mechanism and the electric mechanism. The apparatus includes a mechanism for returning one of the products of electric and magnetic separation to the comminutor while discharging the other to the reject stream. A method for sorting particles composed of a mixture of particles with differing physical and chemical characteristics. The method includes the steps of reducing the size of the particles to liberate subcomponent particles. The method includes the steps of removing particles from the comminutor which are smaller than the feed to the comminutor but coarser than the product of comminution. The method includes the steps of providing the particles to a separation mechanism. Then there are the steps of separating the particles on the basis of size,

density, or electric and magnetic properties. Then there are the steps of returning the appropriate particles to the comminution device for further size reduction and of discharging the other particles from the comminution circuit.

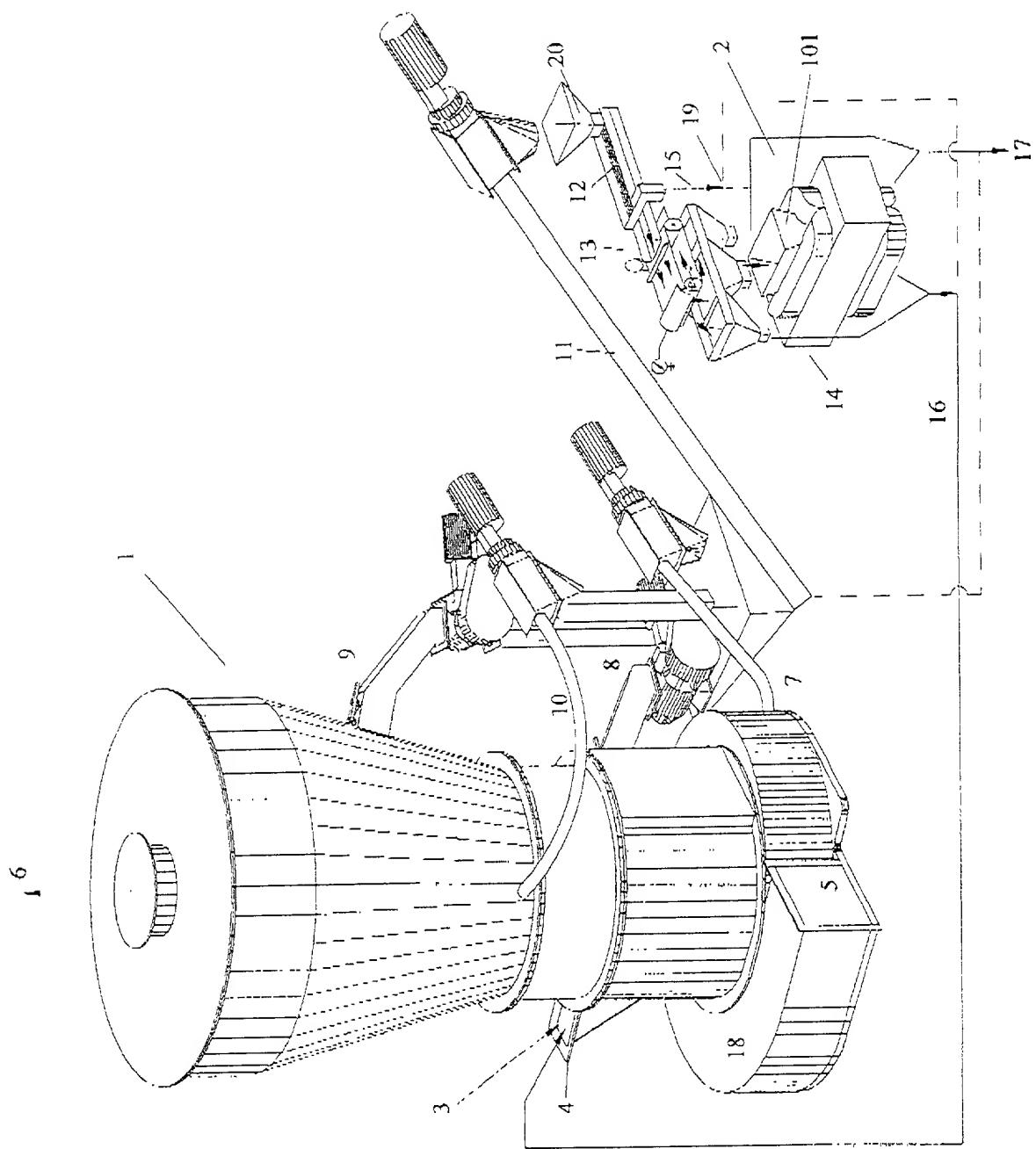


Figure 1

Figure 2

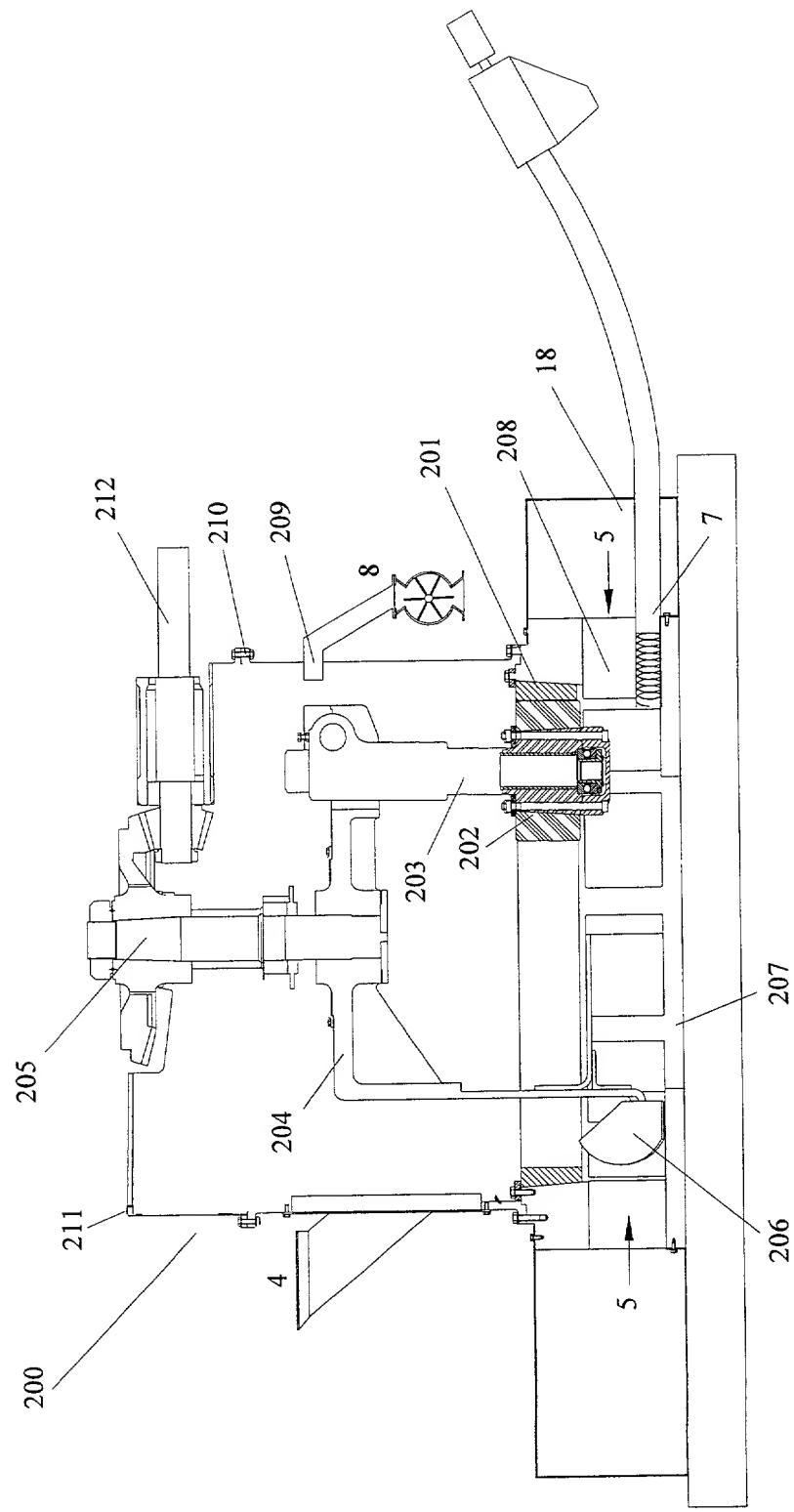


Figure 2

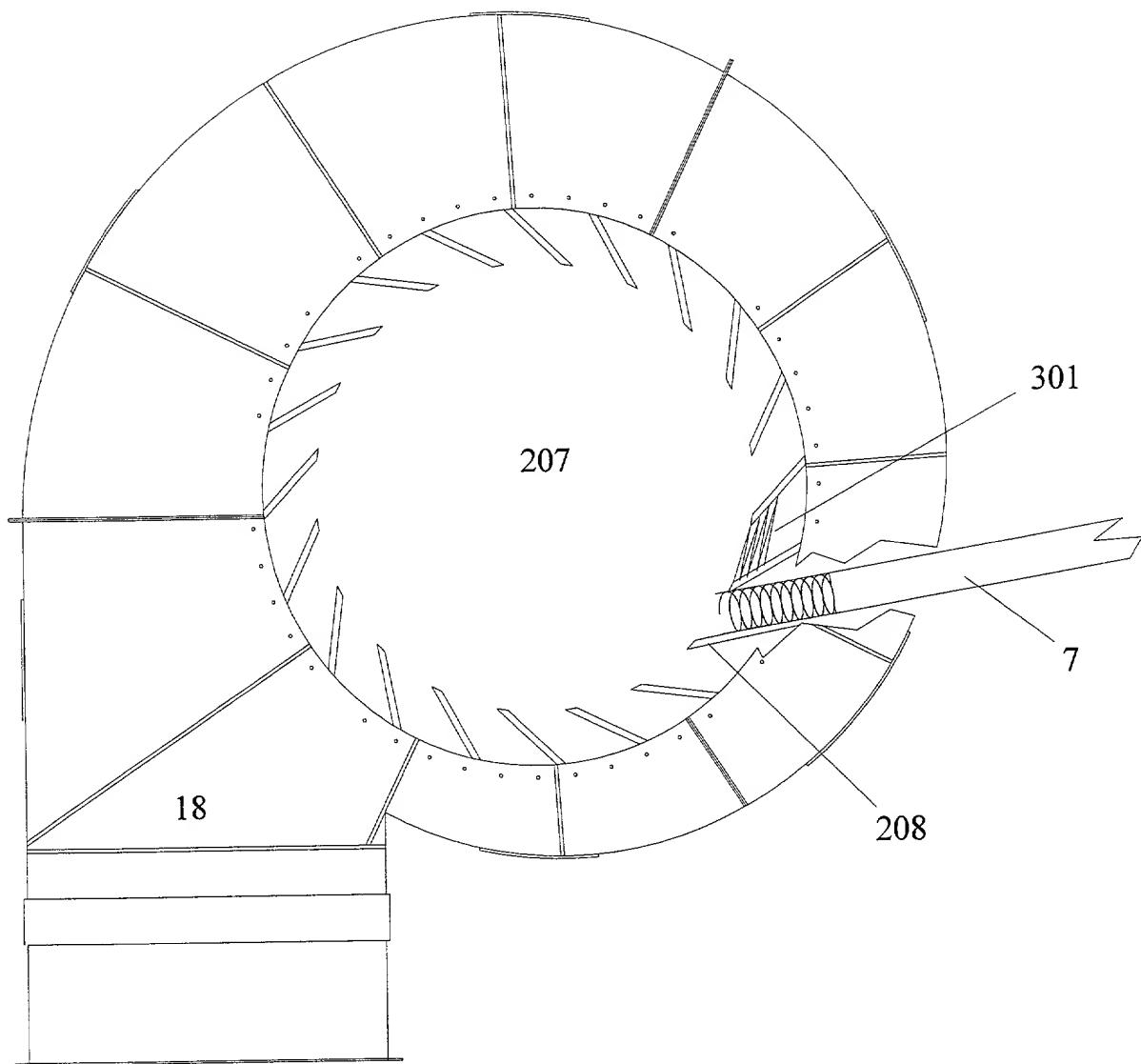


Figure 3

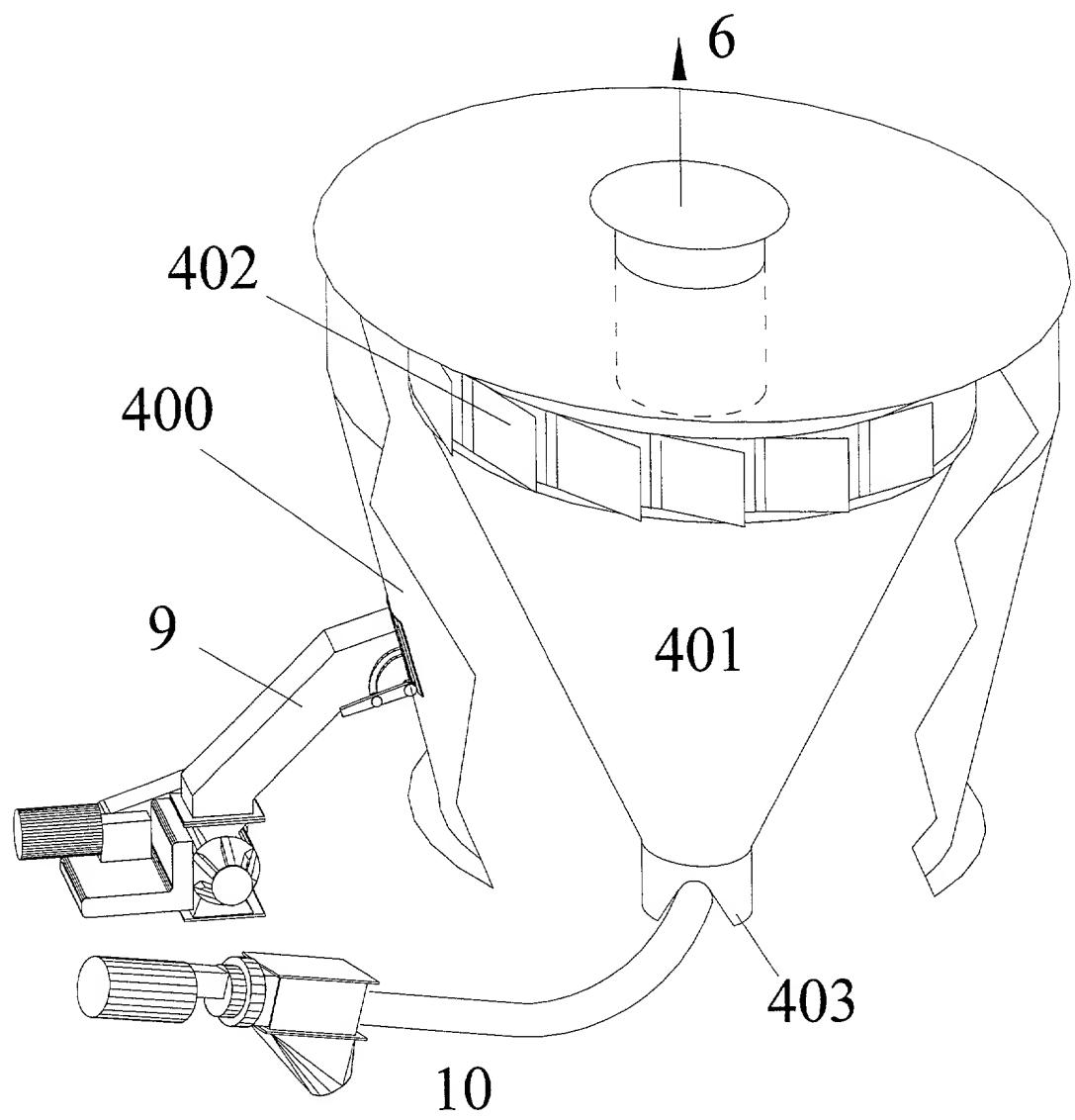


Figure 4

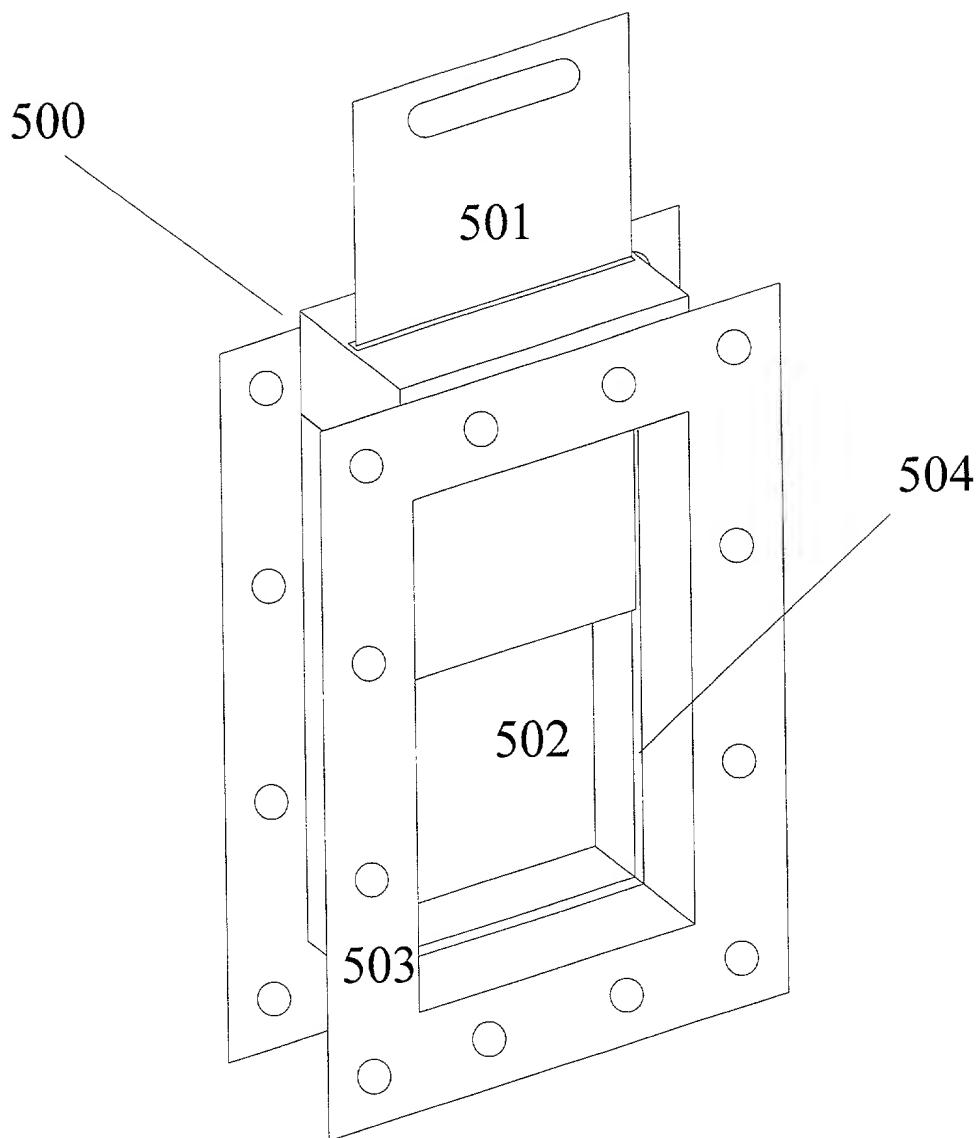


Figure 5

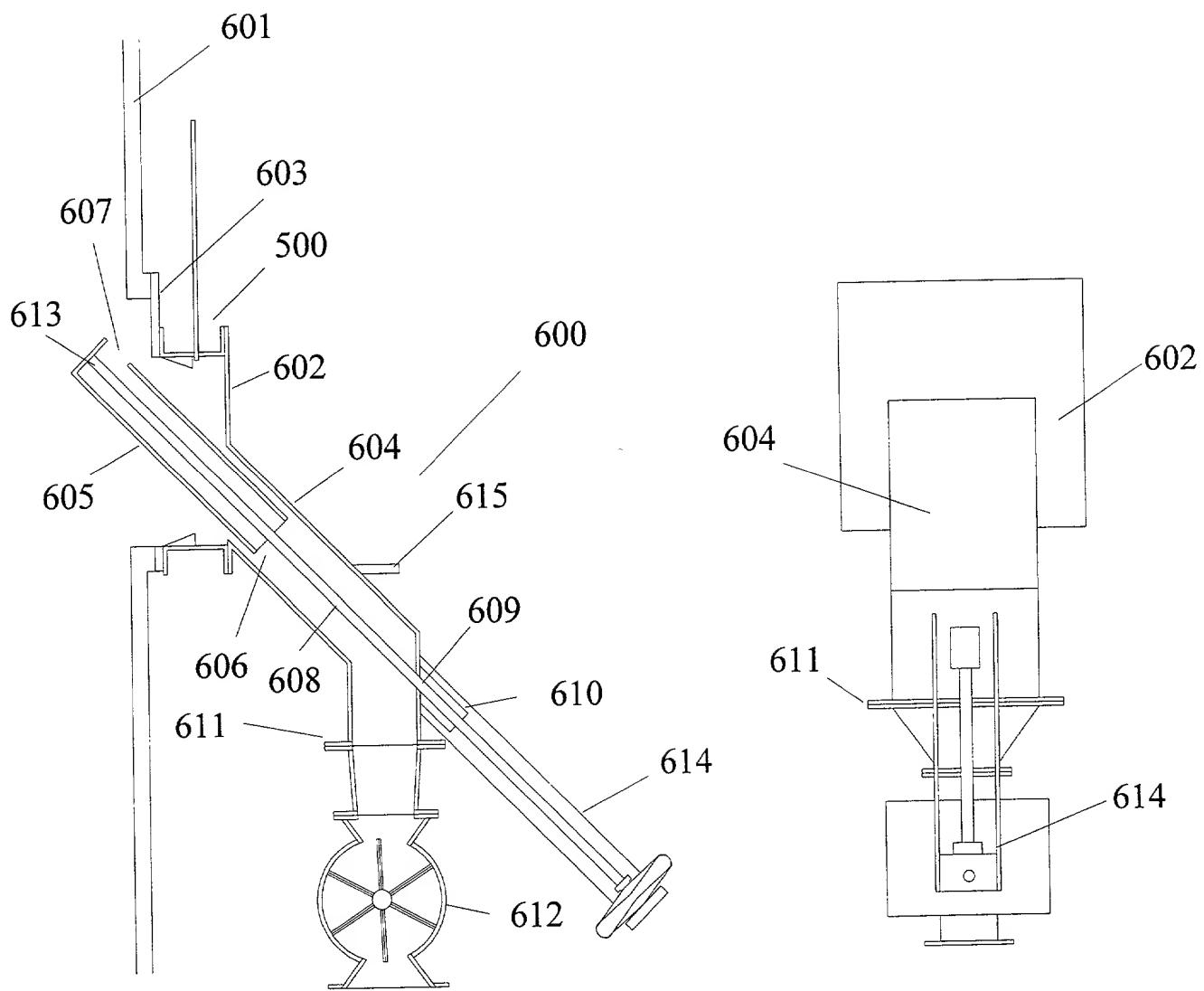


Figure 6

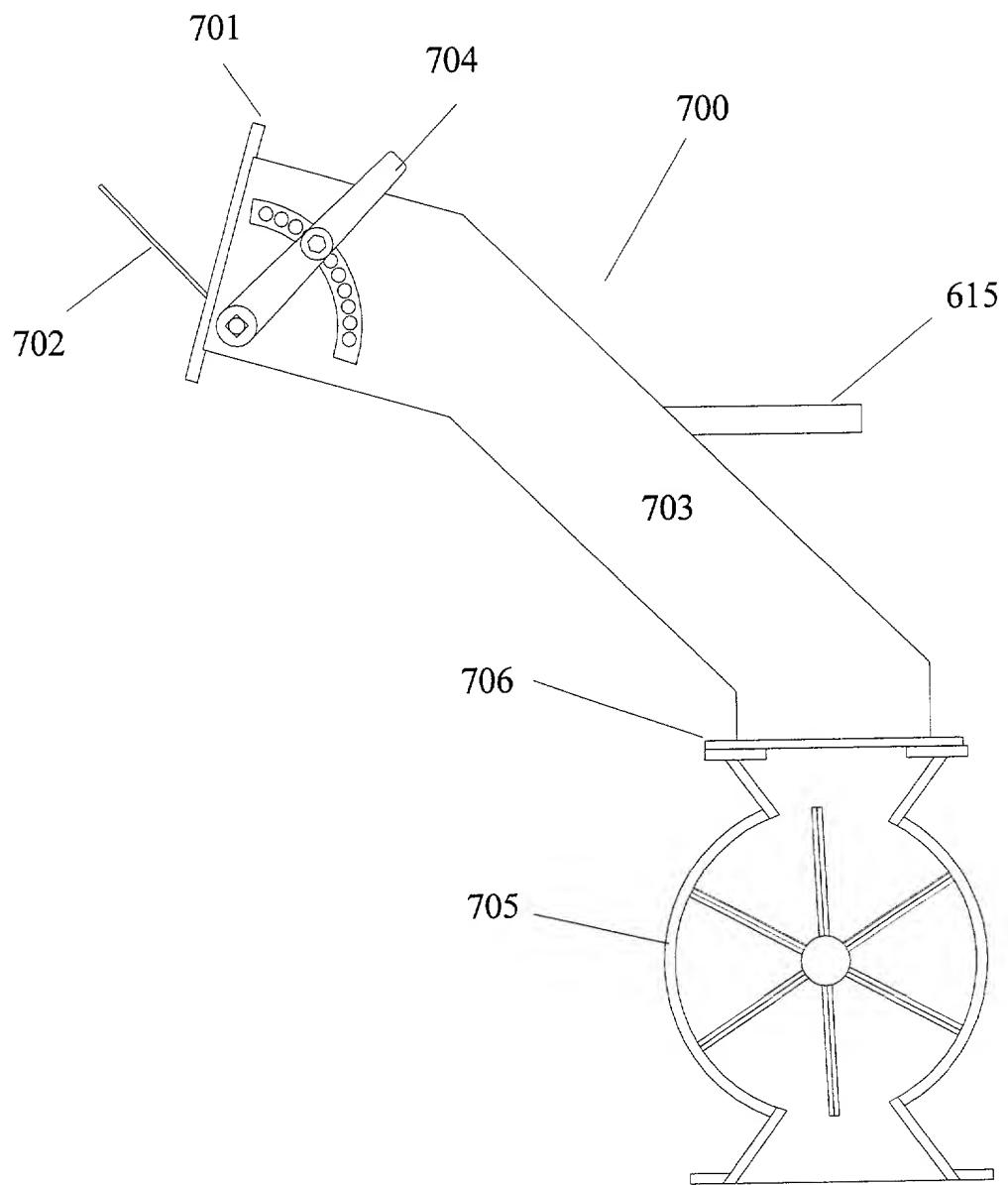


Figure 7

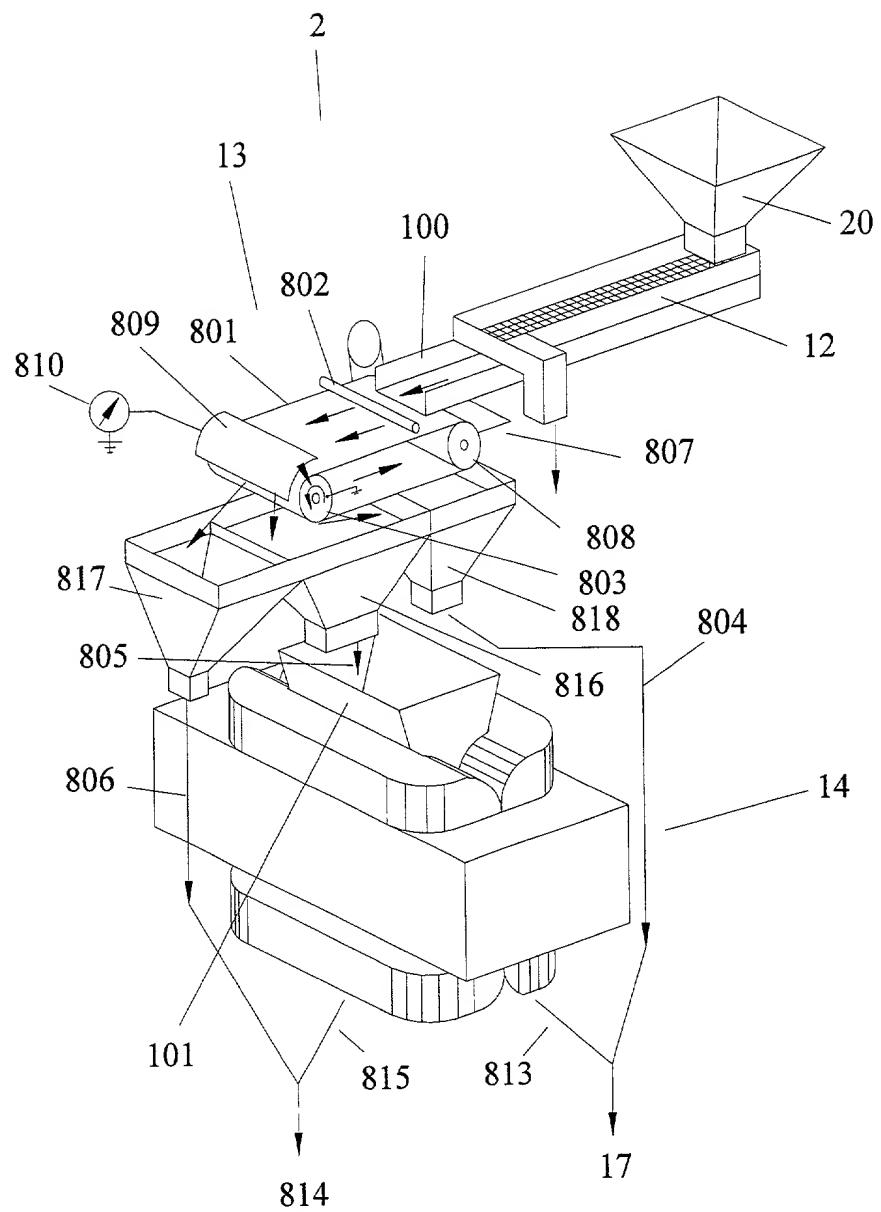


Figure 8

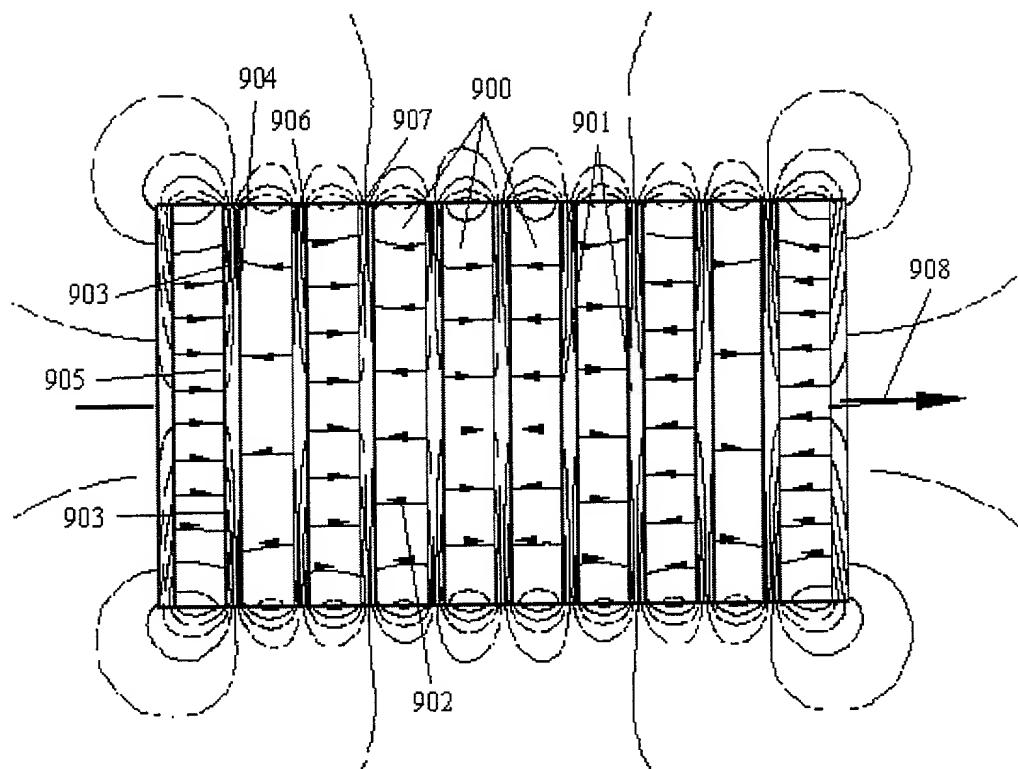


Figure 9

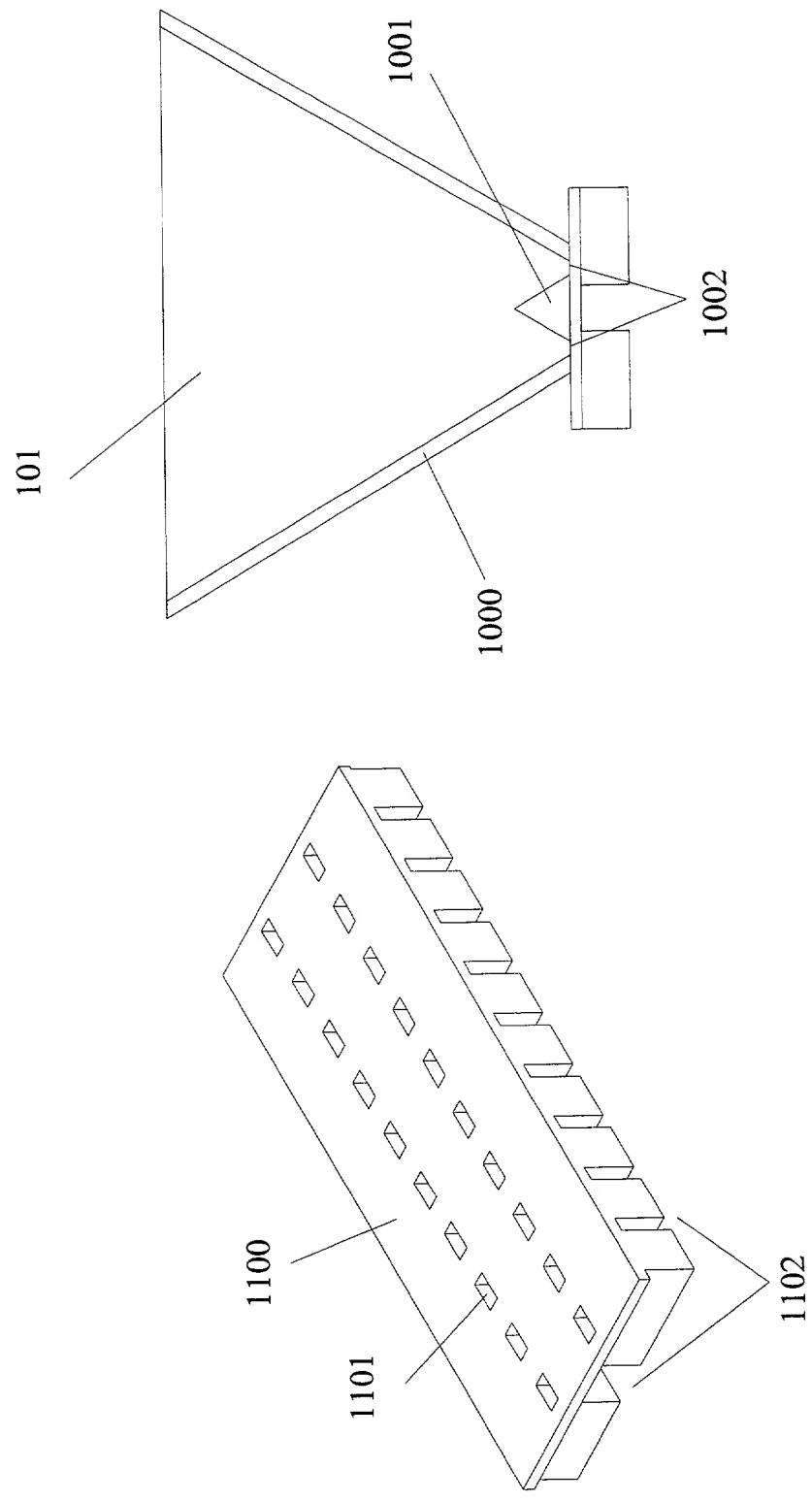


Figure 10

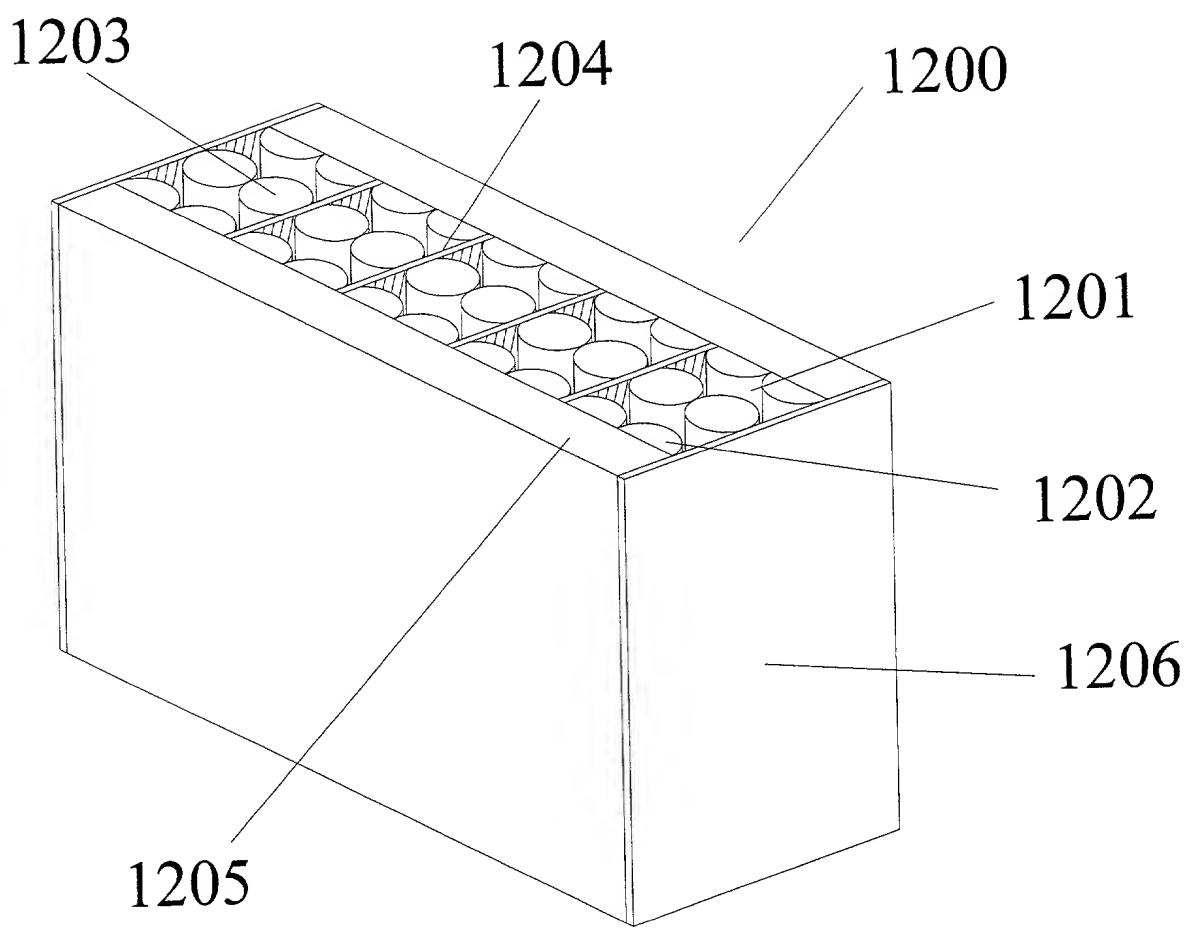


Figure 11

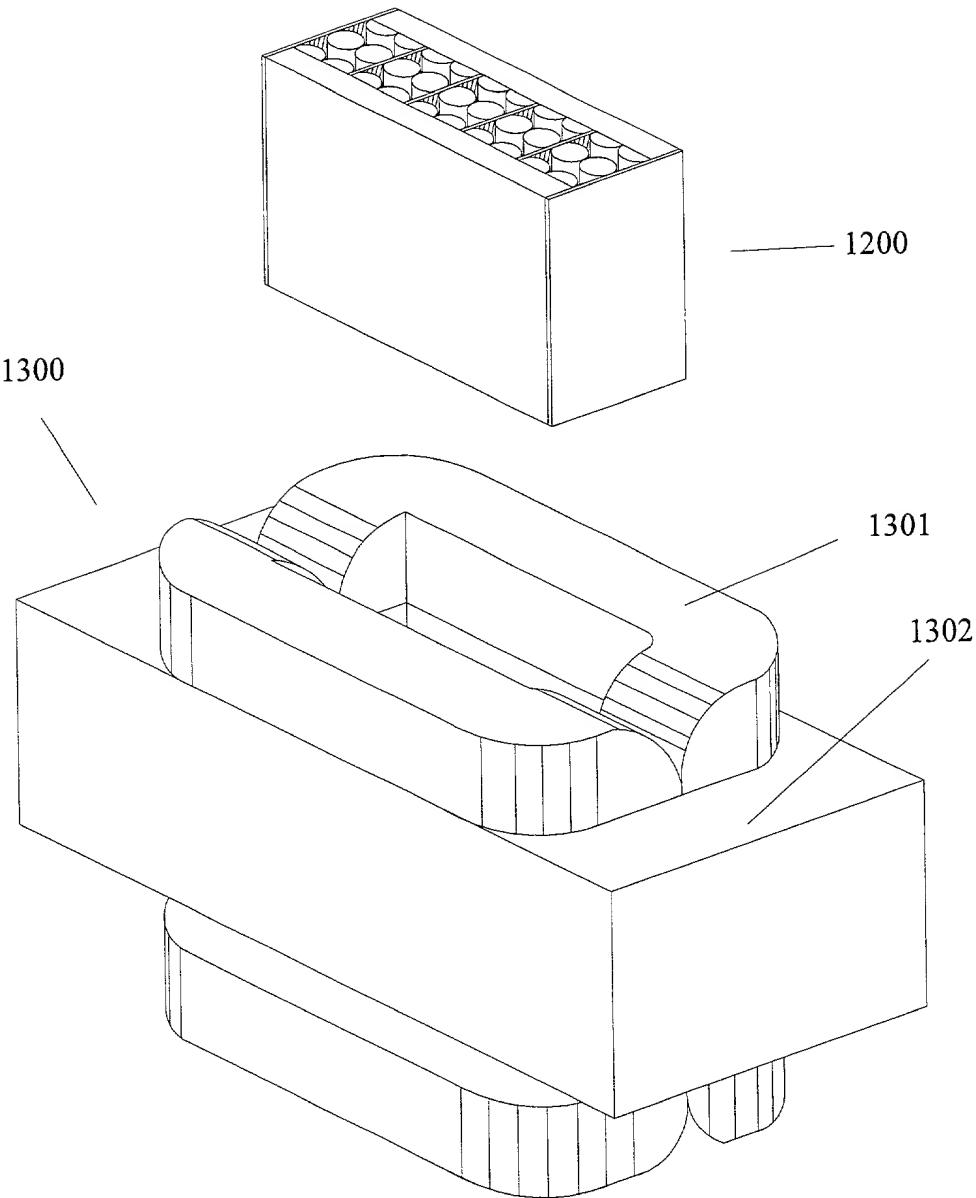


Figure 12

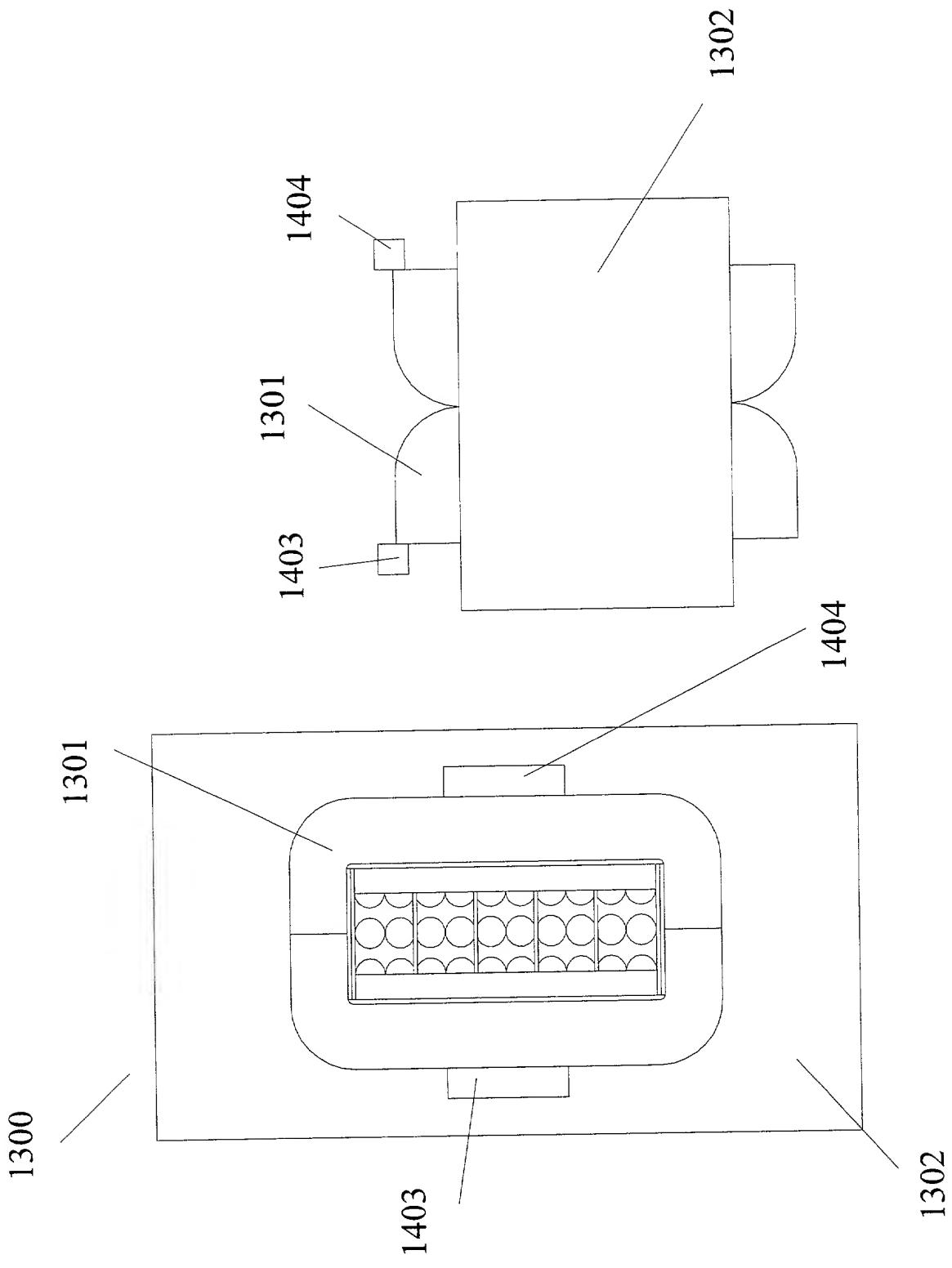


Figure 13

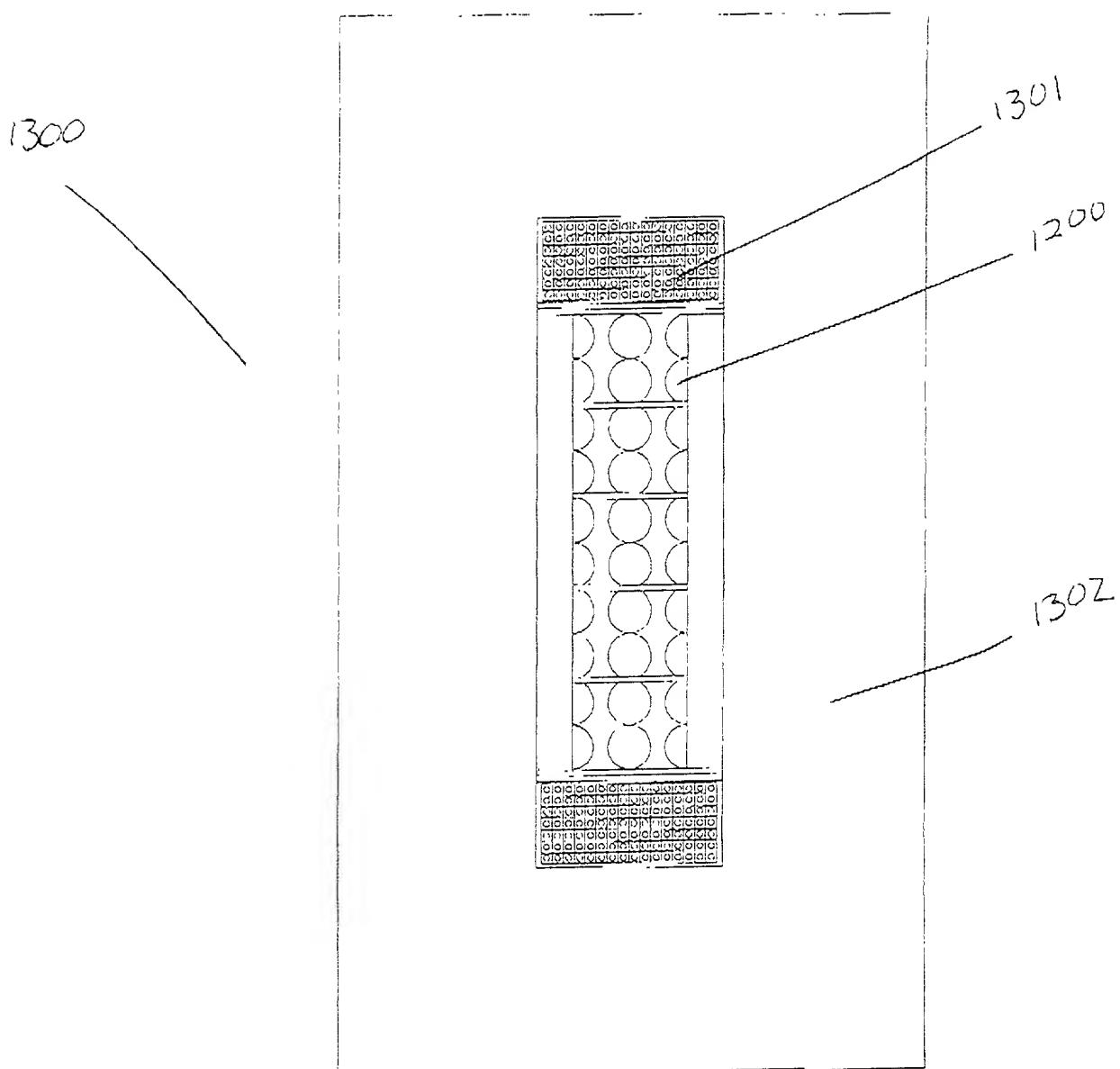


Figure 14

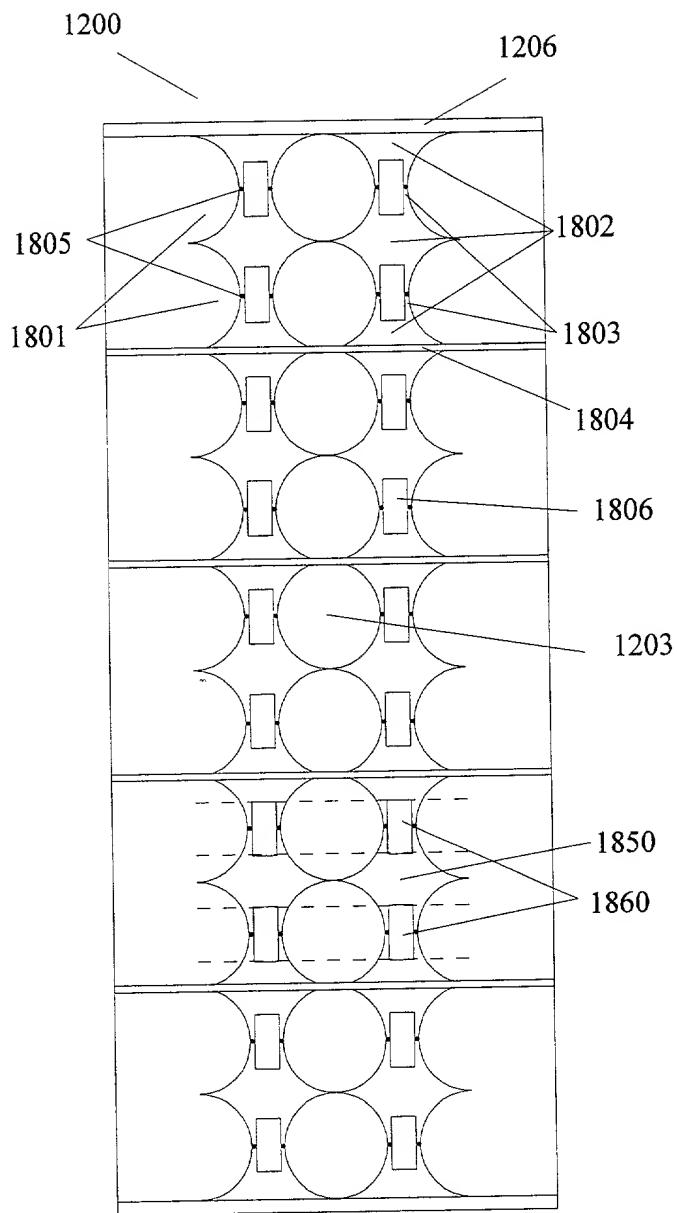


Figure 15

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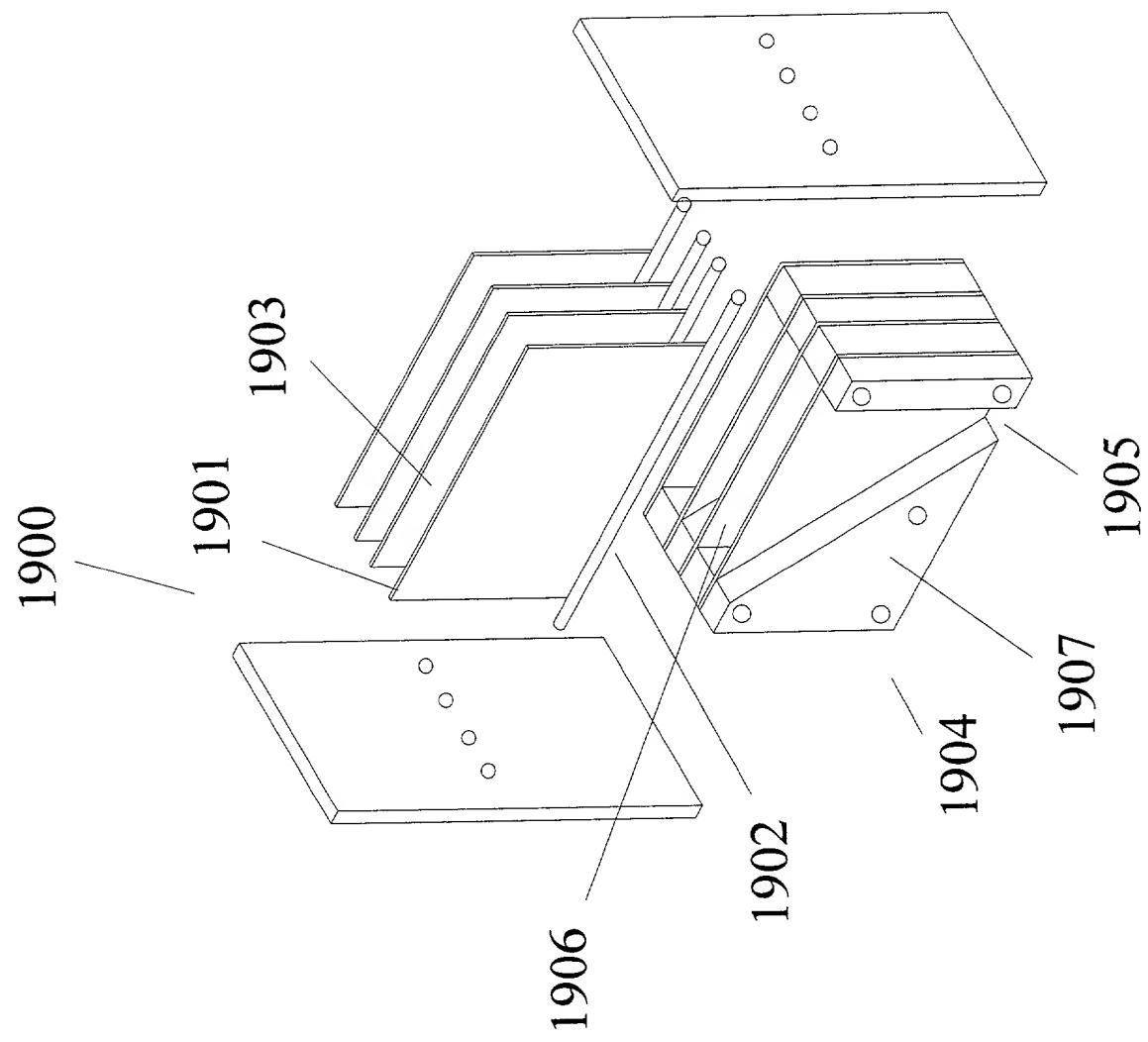


Figure 14

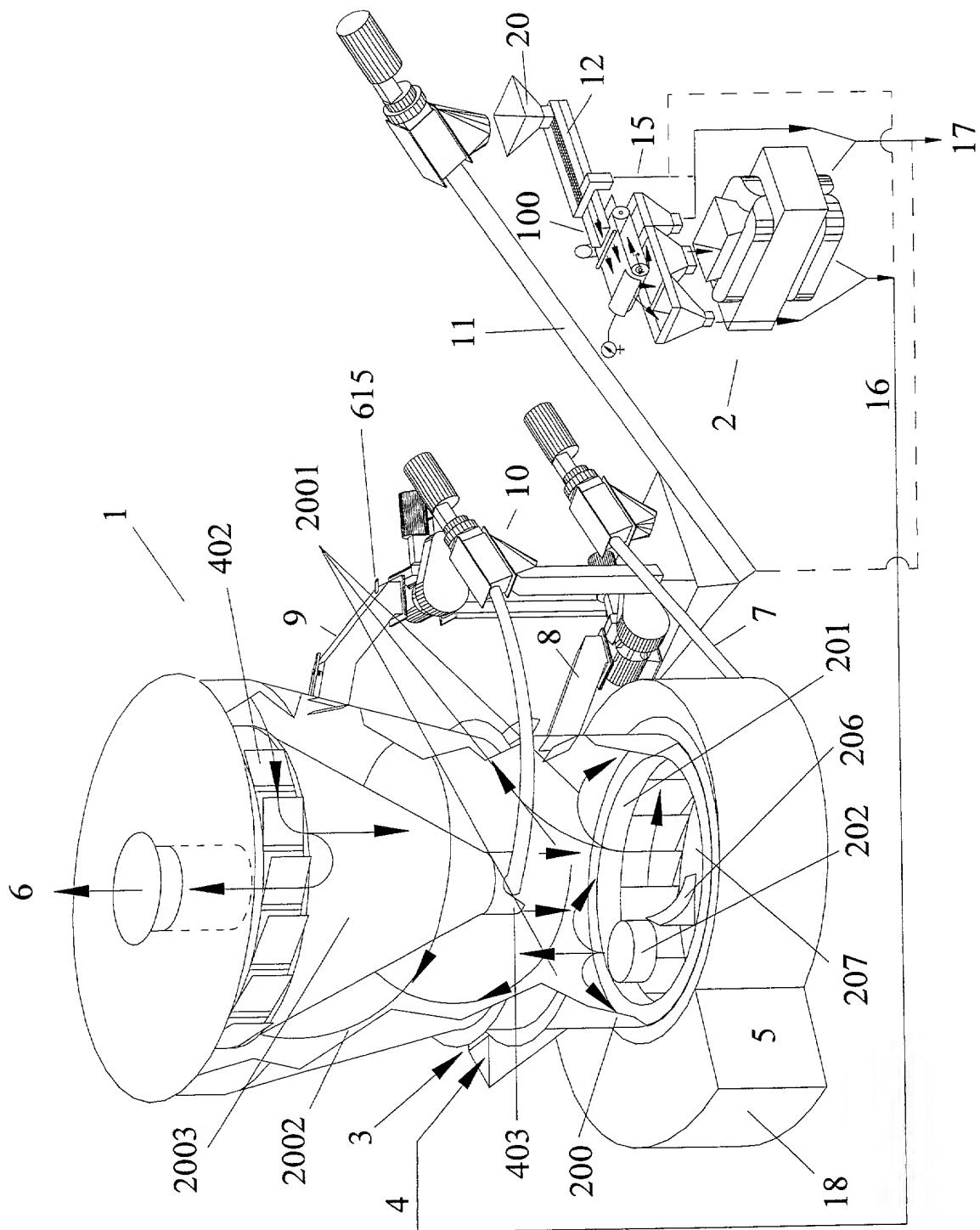


Figure 17

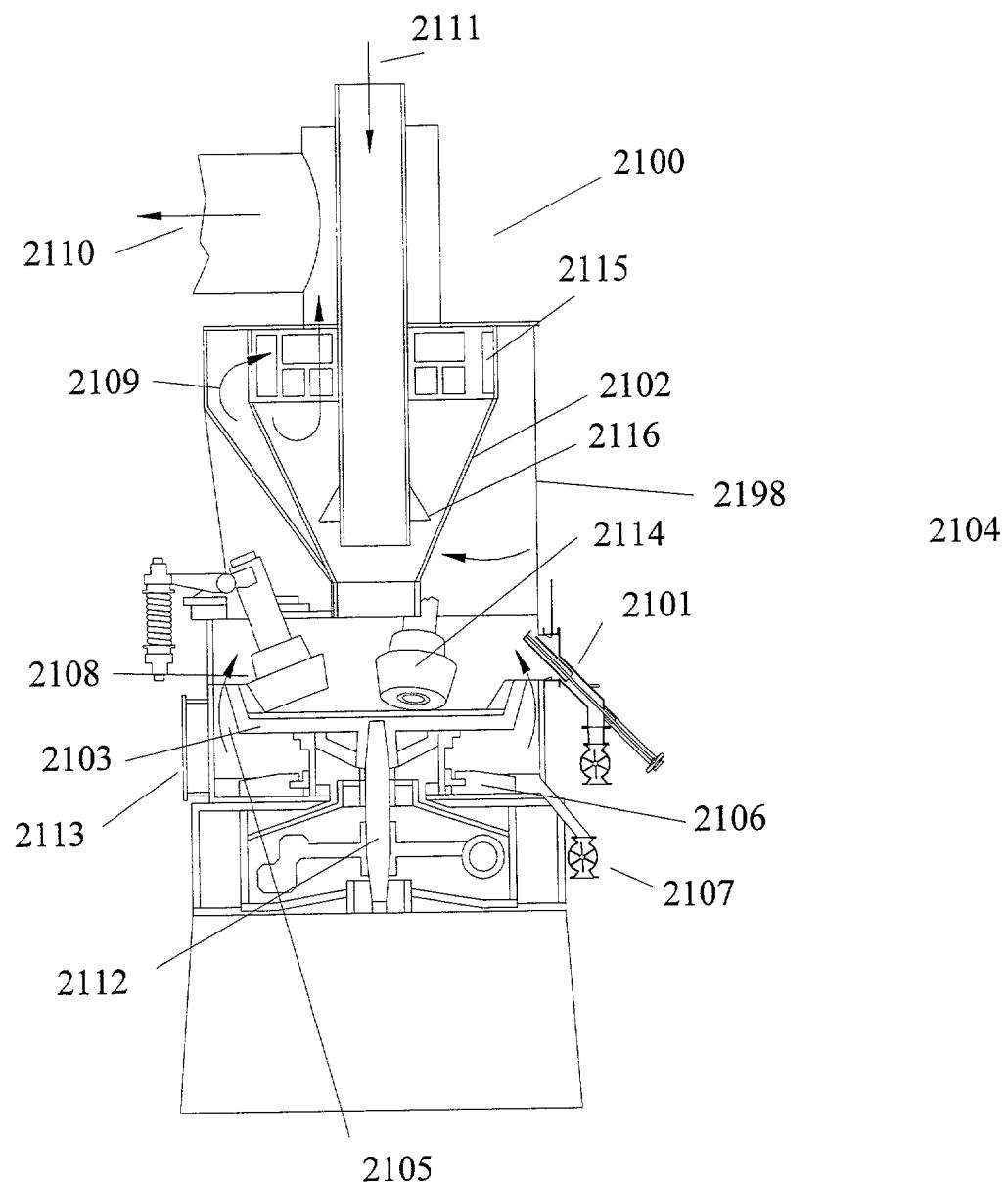


Figure 18

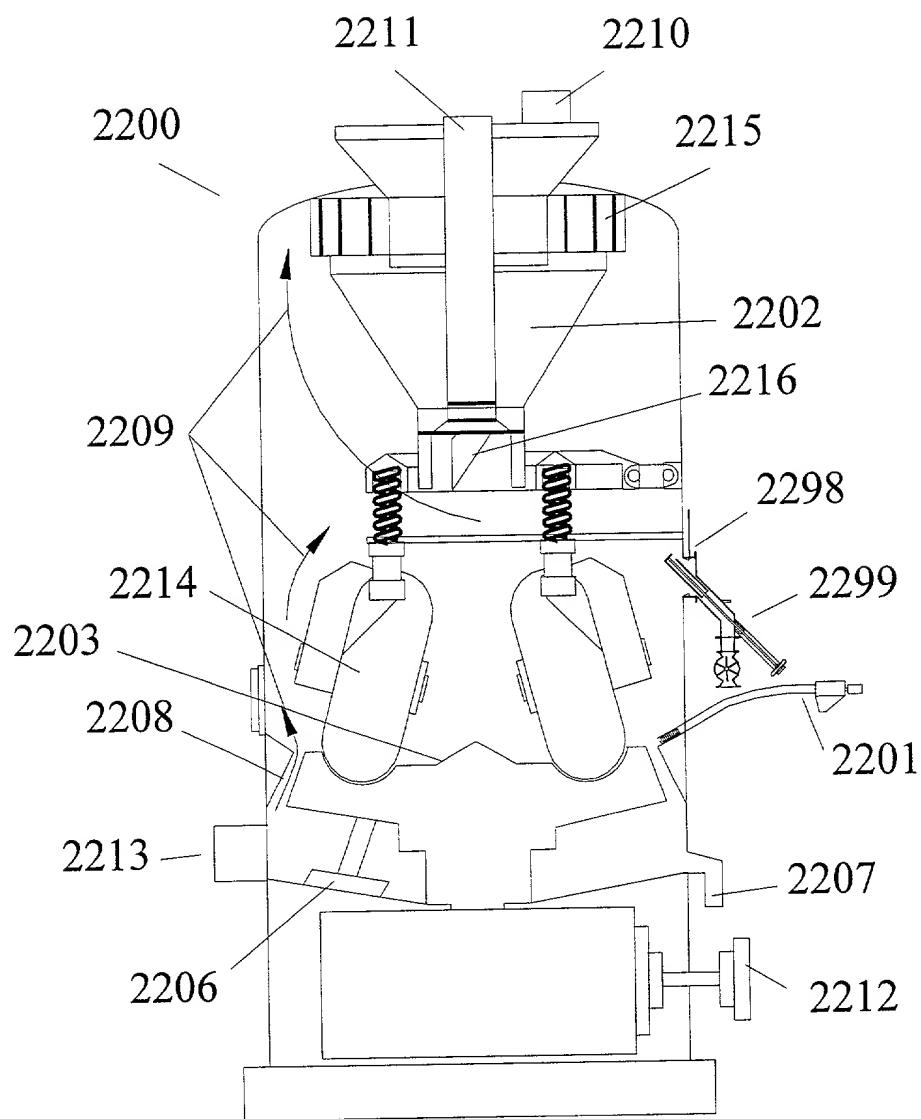


Figure 19

## Declaration and Power of Attorney For Patent Application

### English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

#### METHOD AND APPARATUS FOR SEPARATING MATERIAL

the specification of which

(check one)

is attached hereto.

was filed on \_\_\_\_\_

Application Serial No. 0 / \_\_\_\_\_

and was amended on \_\_\_\_\_

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

#### Prior Foreign Application(s)

#### Priority Claimed

(Number)	(Country)	(Day/Month/Year Filed)	<input type="checkbox"/>	<input checked="" type="checkbox"/>
(Number)	(Country)	(Day/Month/Year Filed)	<input type="checkbox"/>	<input type="checkbox"/>
(Number)	(Country)	(Day/Month/Year Filed)	<input type="checkbox"/>	<input checked="" type="checkbox"/>

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 36, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Page 2 of 2

<u>0 /</u>	(Application Serial No.)	(Filing Date)	(Status)
<u>0 /</u>	(Application Serial No.)	(Filing Date)	(Status)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issued thereon.

**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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Send Correspondence to:

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Direct Telephone Call to: (name and telephone number)

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(Supply similar information and signature for third and subsequent joint inventors.)